OVERVIEW OF PREDICTABILITY RELATED WORK AT NCEP

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Environmental Modeling Center
NOAA/NWS/NCEP

Acknowledgements:

Colleagues at EMC, HPC, CPC, and outside collaborators

http://wwwt.emc.ncep.noaa.gov/gmb/ens/index.html

OUTLINE / SUMMARY

RECENT CHANGES
CURRENT CONFIGURATION
RESEARCH / PLANS
USAGE NOTES

For

- **GLOBAL ENSEMBLE FORECAST SYSTEM**
  - 4 times per day, increased resolution from Dec. 2003
  - North American Ensemble Forecast System
- **REGIONAL ENSEMBLE FORECAST SYSTEM**
  - Multiple model versions
- **COUPLED OCEAN-ATMOSPHERE FORECAST SYSTEM**
  - New coupled model, experiments with bred vectors
- **WINTER STORM RECONNAISSANCE PROGRAM**
  - Operational program to adaptively collect observations
  - THORPEX connection – similar concept tested in Atlantic Regional Campaign

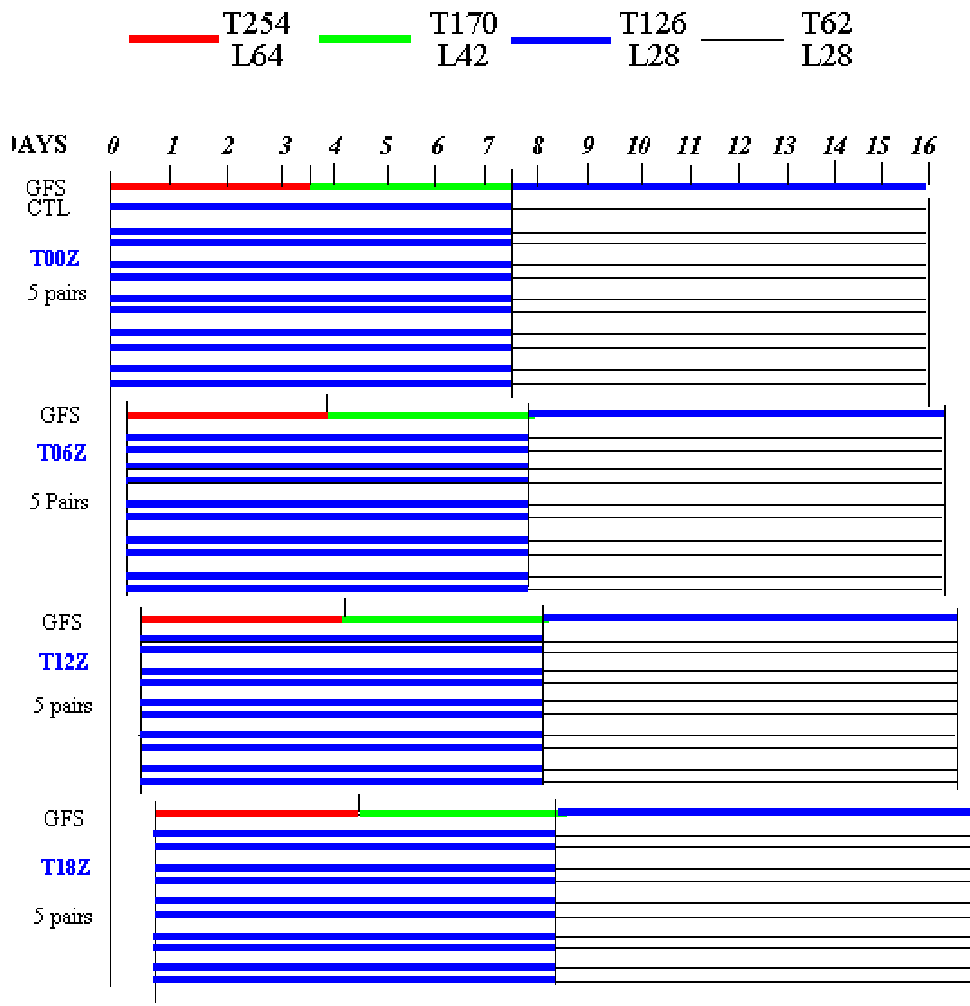
NCEP GLOBAL ENSEMBLE FORECAST SYSTEM

R. Wobus, Y. Zhu

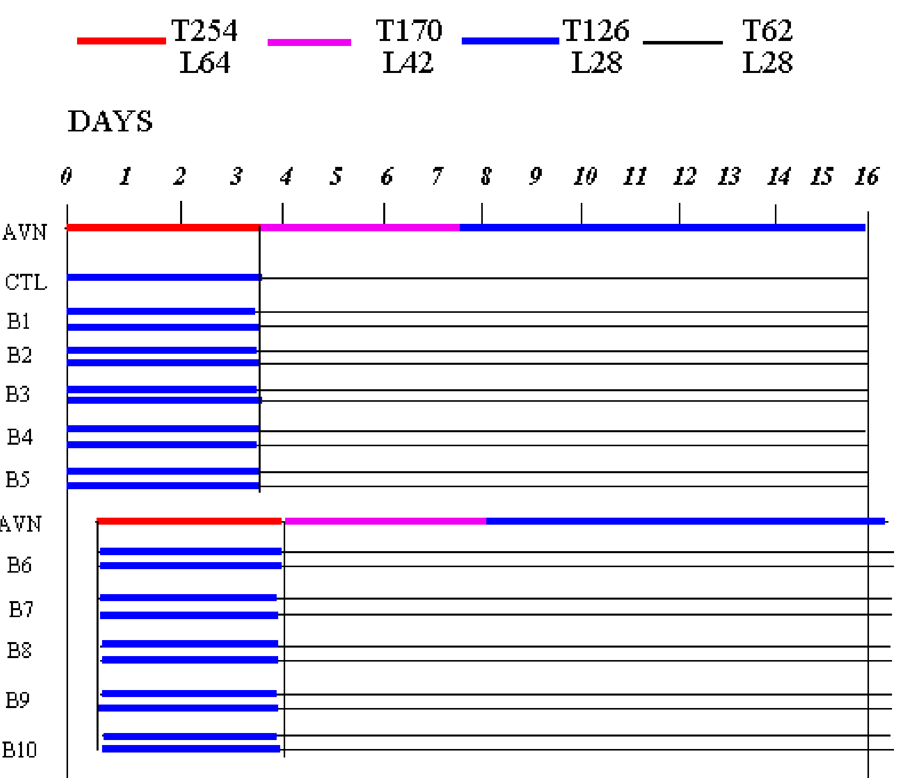
RECENT UPGRADE (Apr. 2003)

10/50/60% reduction
in initial perturbation size over
NH/TR/SH

NEW CONFIGURATION DECEMBER 2003



CURRENT SYSTEM

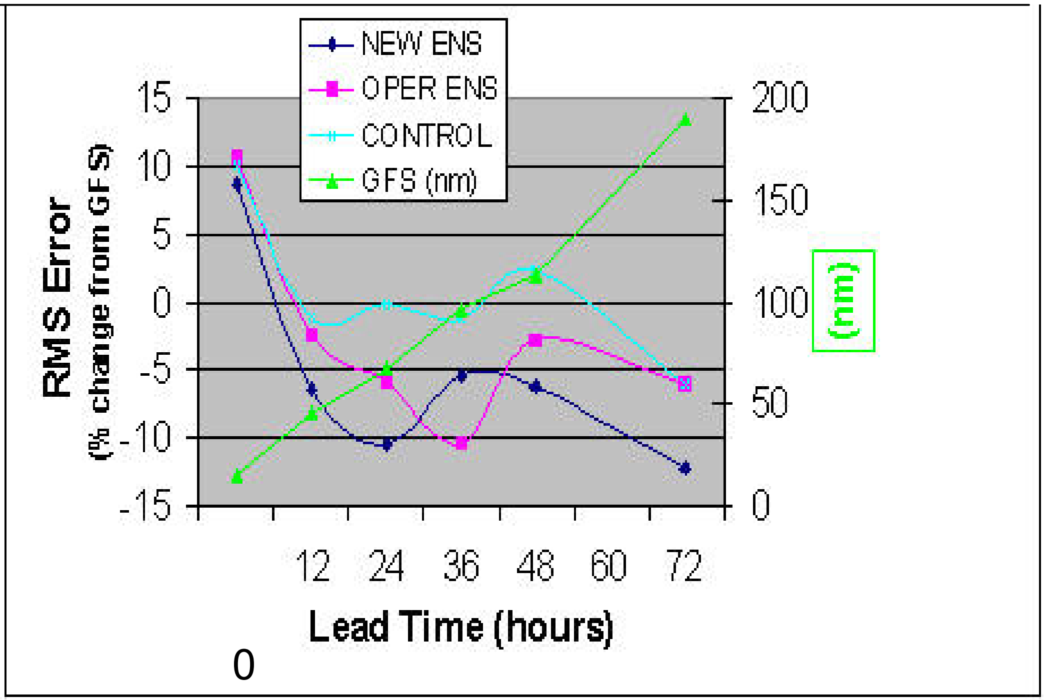


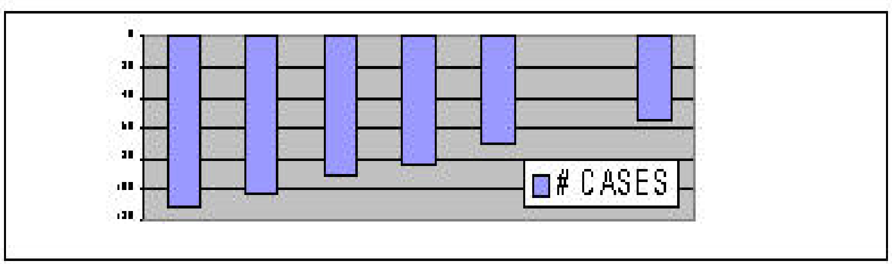
TROPICAL STORM TRACK ERRORS

T. Marchok

RECENT UPGRADE

Tested for Aug 24 – Sept 30 2002





1) Ensemble mean error lower than GFS hires control

2) New reduced initial amplitude improves performance

3) SH scores greatly improved

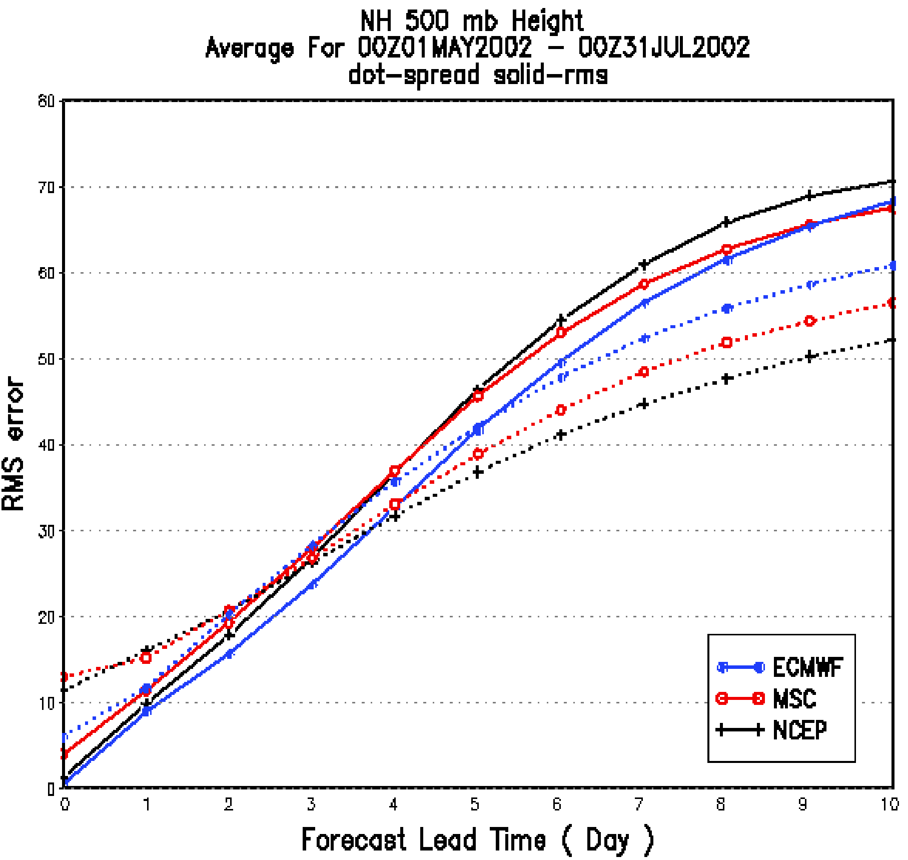
3-WAY INTERCOMPARISON: RESEARCH
ECMWF, MSC, NCEP

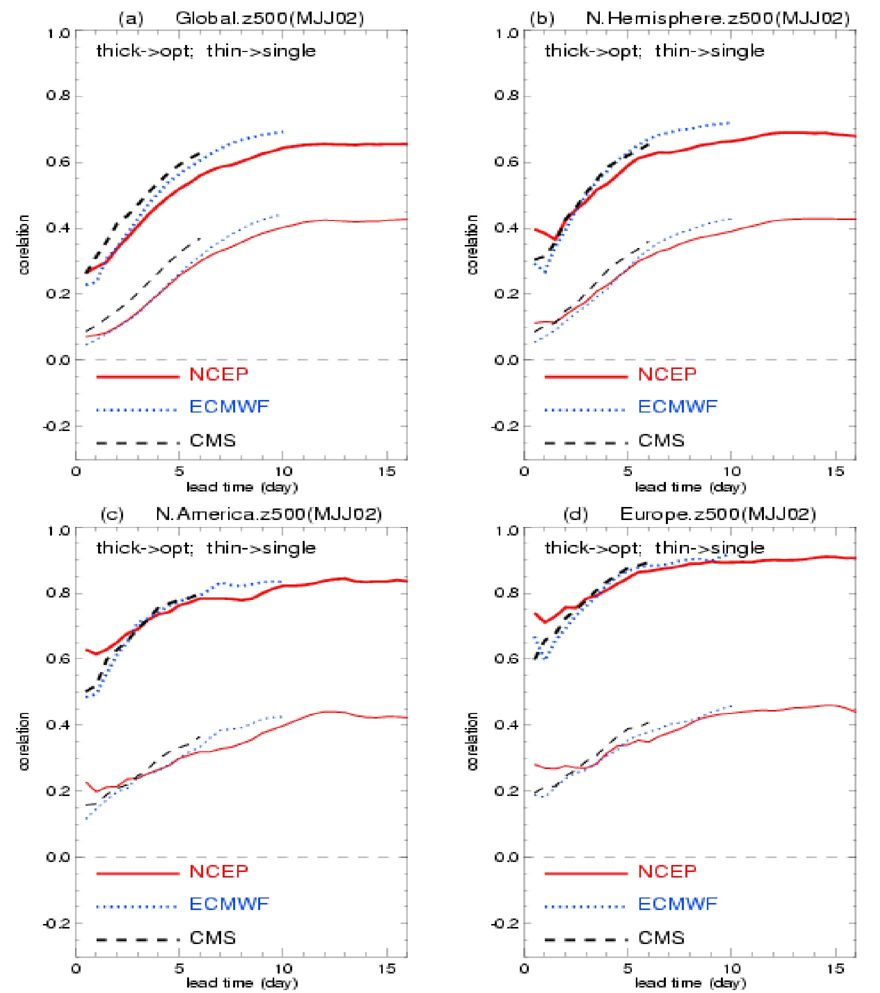
Buizza, Houtekamer et al.

LESSONS LEARNT FOR NCEP

Growth of spread is too low =>
Need for stochastic perturbations

Orthogonalization of perturbtns may help =>
Apply ETKF for generating perturbations





USE ETKF FOR RESCALING BRED PERTURBATIONS

Wei, based on Bishop & Wang

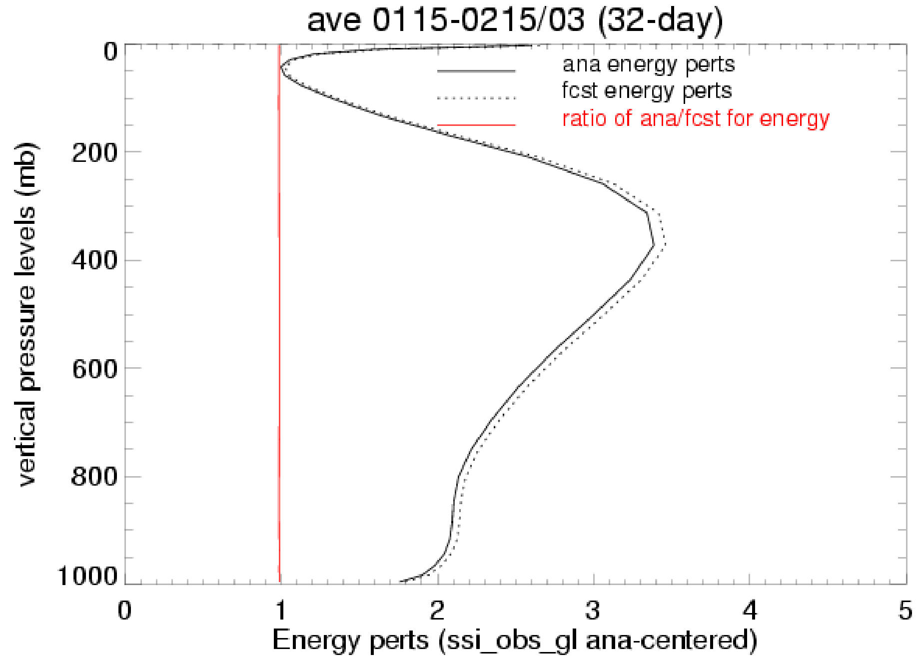
ADVANTAGES COMPARED TO CURRENT REGIONAL RESCALING:

1) Effect of actual obs. error/locations considered
2) Orthogonalization of initial perturbations
3) 6-hr cycling
4) Can be further developed into DA scheme

VERTICAL DISTRIBUTION OF TOTAL ENERGY

Reflects combined effect of

- *Atmospheric instabilities and*
- *Observation locations/errors*

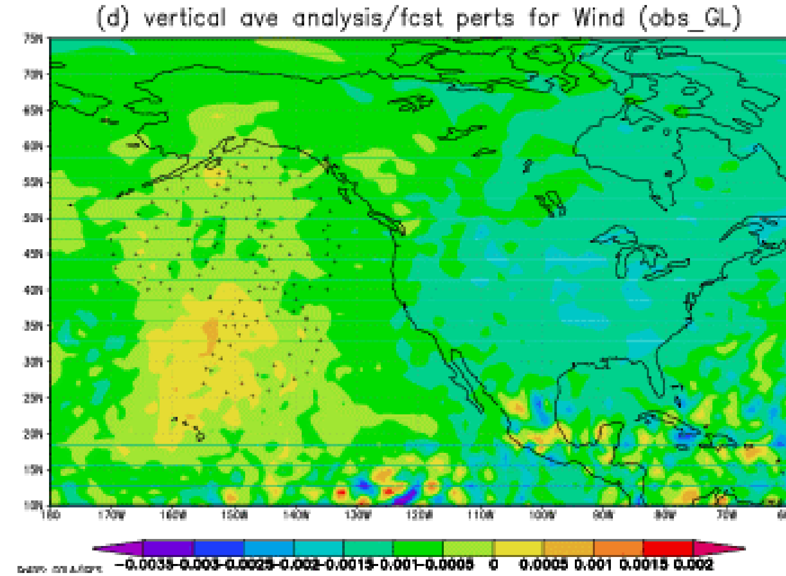


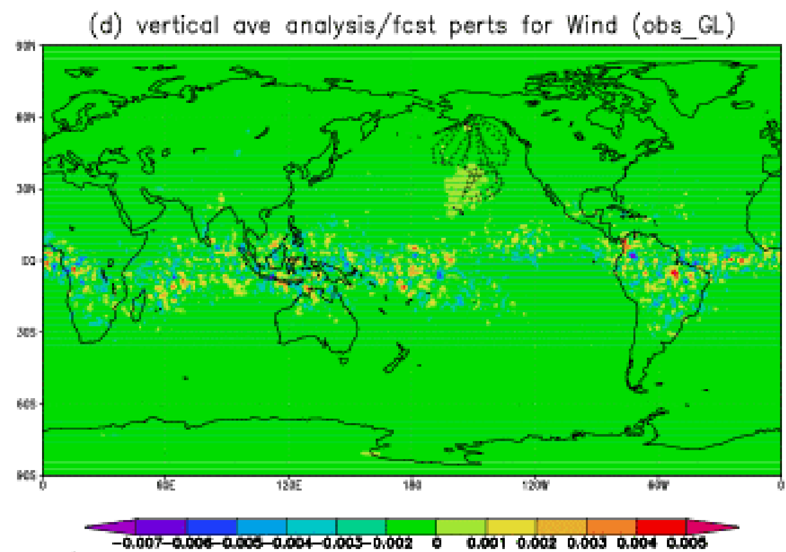
HORIZONTAL DISTRB. OF WIND

When ~20 dropsondes considered

7-Case WSR average initial spread

Reflects reduced uncertainty in IC





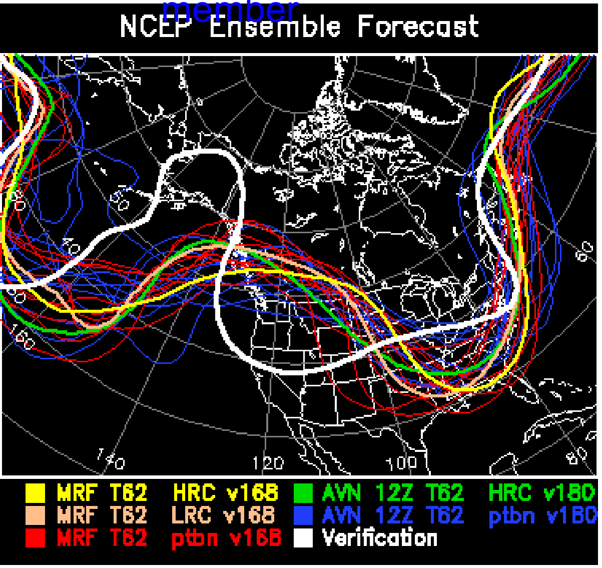
EXAMPLE WHERE MODEL MAY HAVE FAILED

D. Hou, Y. Zhu

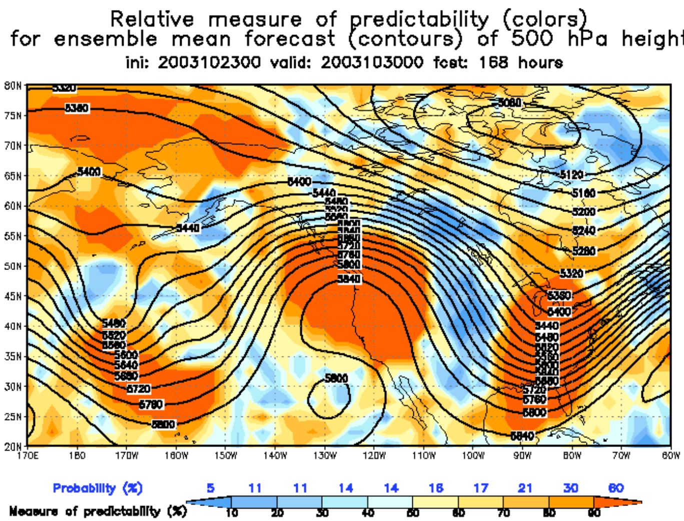
STOCHASTIC PERTURBATIONS NEEDED TO:

1) Increase growth of spread;
2) Avoid problems like below

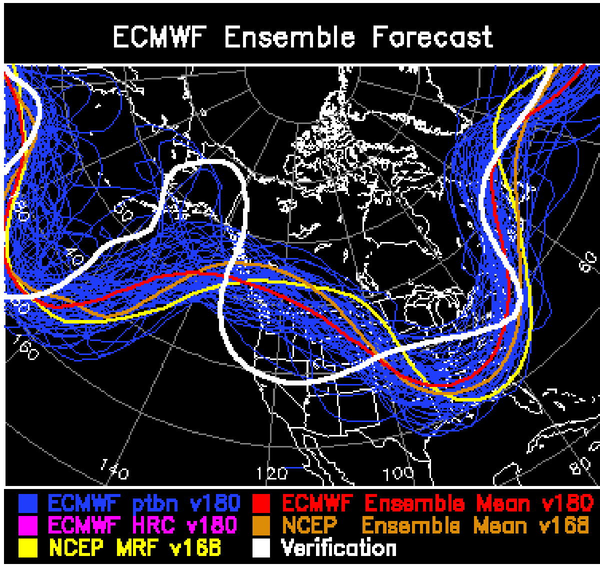
Day 7, 0 member



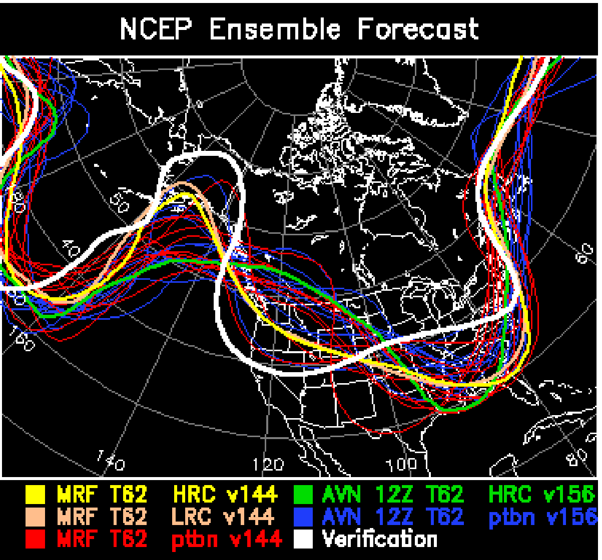
Day 7, overconfidence?



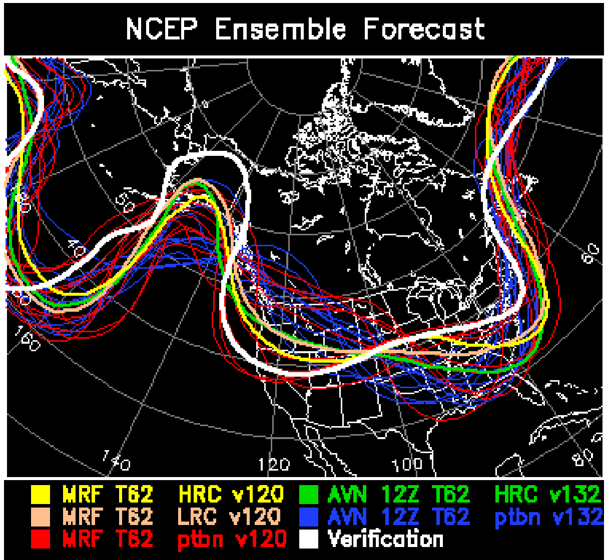
Day 7.5, 1 member?



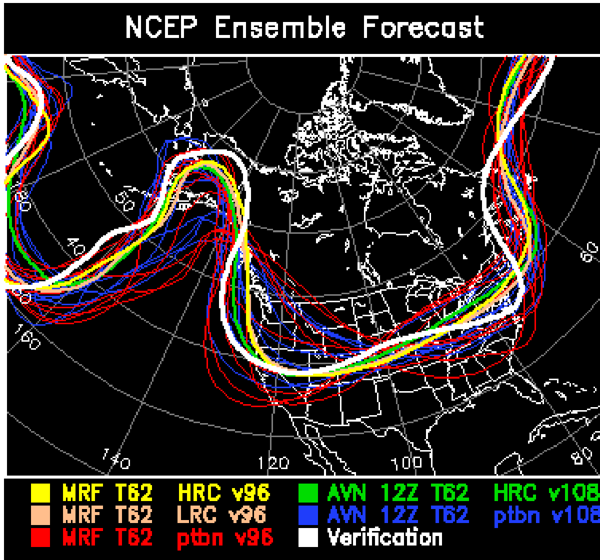
Day 6, 2 members



Day 5, several members



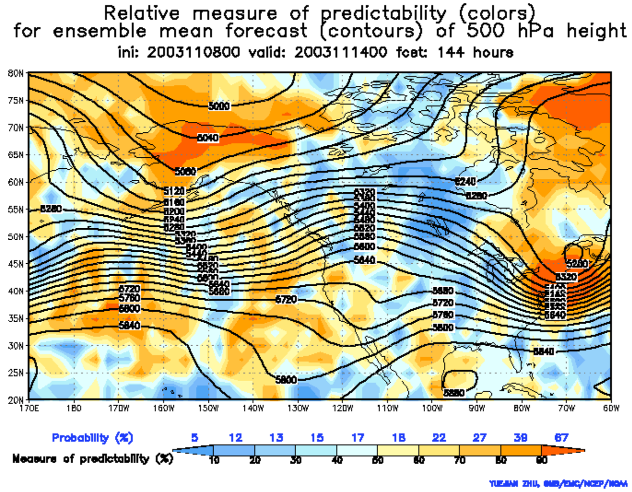
Day 4, still large uncertainty



PRODUCTS

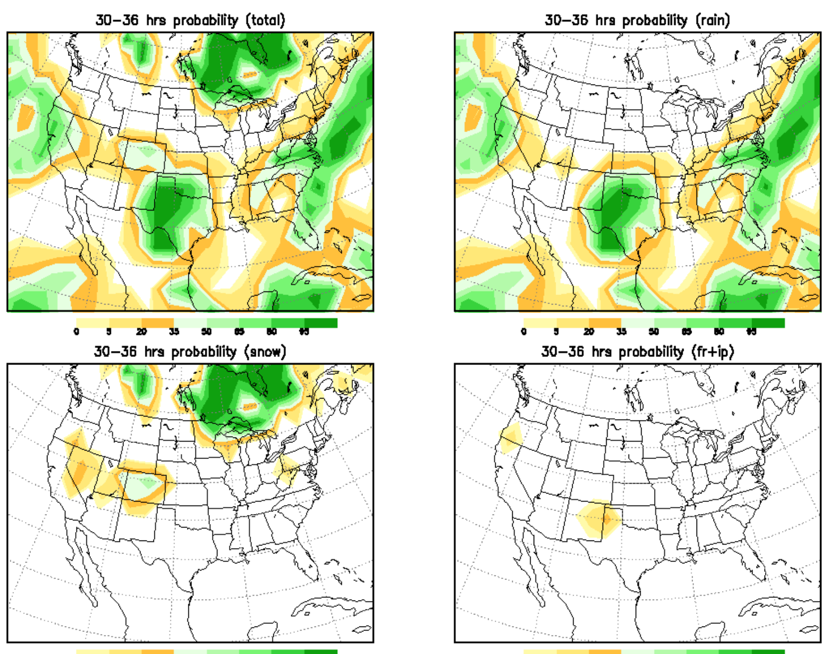
Y. Zhu

RELATIVE MEASURE OF PREDICTABILITY, GLOBAL



PRECIPITATION TYPE, GLOBAL ENSEMBLE

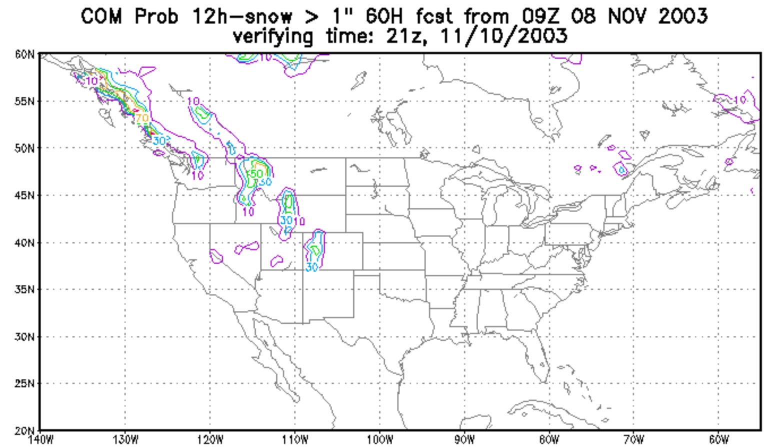
Ensemble Probability Forecast (Initial: 2003110600)
>0.254mm



B. Zhou

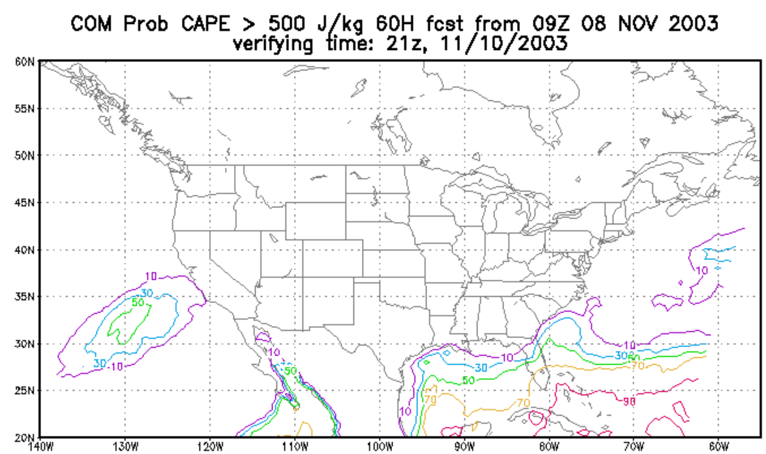
SNOWFALL, REGIONAL

Winter Weather Experiment



CAPE, REGIONAL

Severe Storms, Aviation

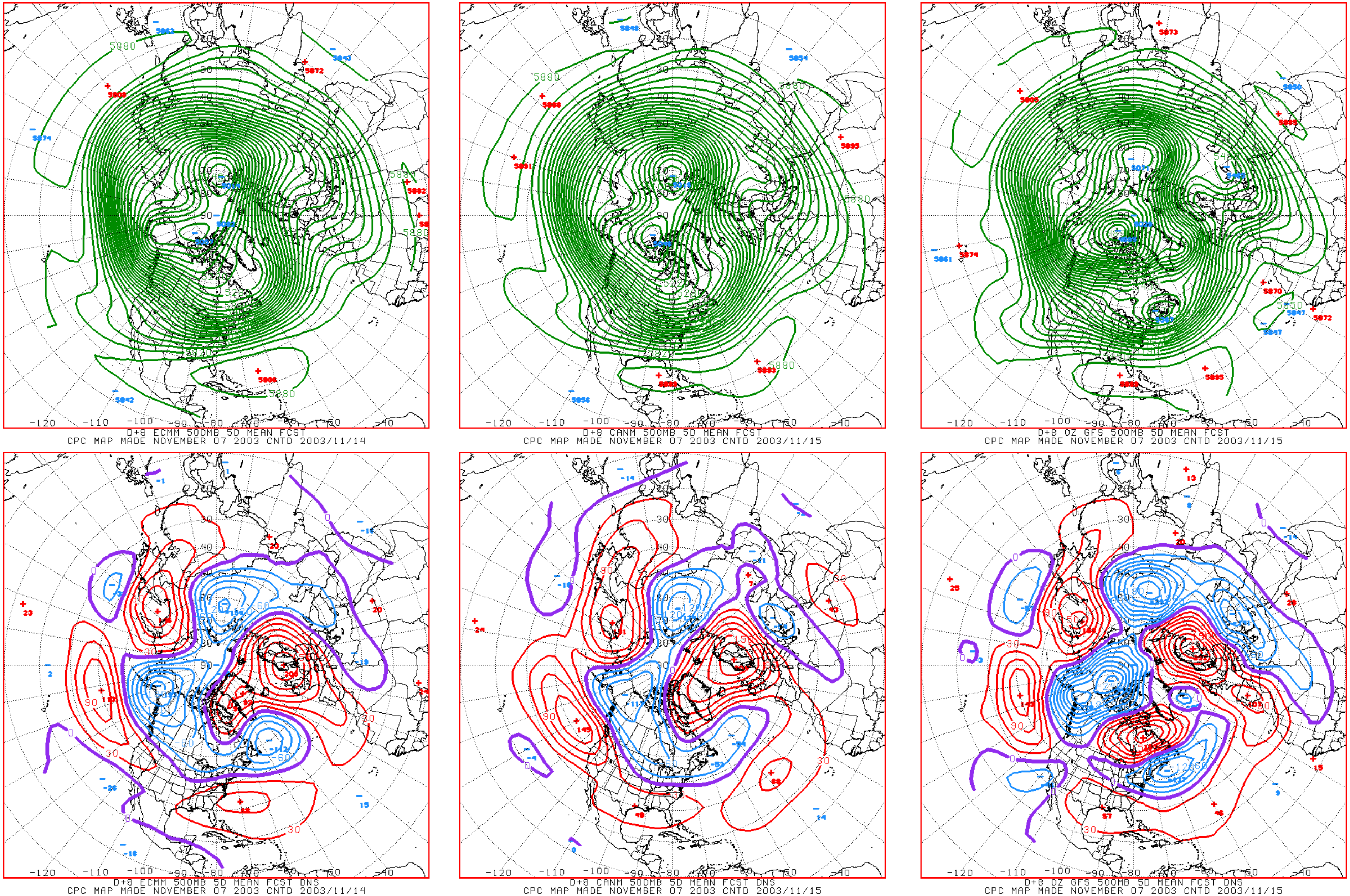


3-WAY INTERCOMPARISON: CPC OPERATIONS

500 hPa height ensemble mean and climate anomaly

R. Schechter
K. Pelmann

ECMWF **NCEP** **MSC**



NORTH AMERICAN ENSEMBLE FORECAST SYSTEM PROJECT

GOALS: **Accelerate improvements in operational weather forecasting**

through Canadian-US collaboration

Seamless (across boundary and in time) suite of products

through joint Canadian-US operational ensemble forecast system

PARTICIPANTS: Meteorological Service of Canada (CMC, MRB)

US National Weather Service (NCEP)

PLANNED ACTIVITIES: Ensemble data exchange (June 2004)

Research and Development -*Statistical post-processing*

(2003-2007) *-Product development*

-Verification/Evaluation

Operational implementation (2004-2008)

POTENTIAL PROJECT EXPANSION / LINKS:

Shared interest with THORPEX goals of

Improvements in operational forecasts

International collaboration

Expand bilateral NAEFS in future

Entrain broader research community

Multi-center / multi-national ensemble system:

MOA with Japan Meteorological Agency

NAEFS - BENEFITS

J.-G. Desmarais et al.

Two independently developed systems combined, using different:

- Analysis techniques
- Initial perturbations
- Models

Joint ensemble may capture new aspects of forecast uncertainty

Procedures / software can be readily applied on other ensembles:

- ECMWF
- JMA
- FNMOC, etc

Basis for future multi-center ensemble

Collaborative effort

Broaden research scope -	Enhanced quality
Share developmental tasks -	Increased efficiency
Seamless operational suite -	Enhanced product utility

Framework for future technology infusion (MDL, NOAA Labs, Univs.)

THORPEX OBJECTIVES

INTERNATIONAL PROGRAM

SCIENCE GOAL:

Promote research leading to new techniques in:

Observations *(Collect data)*

Data assimilation *(Prepare initial cond.)*

Forecasting *(Run numerical model)*

Socioeconomic Applications

(Post-process, add value, apply)

SCIENTIFIC RESEARCH MUST ENABLE SERVICE GOALS

SERVICE GOAL:

Accelerate improvements in utility of 1-14 day forecasts for high impact weather

THORPEX ANSWER:

Develop new paradigm for weather forecasting through

Enhanced collaboration: Internationally

Among different disciplines

Between research & operations

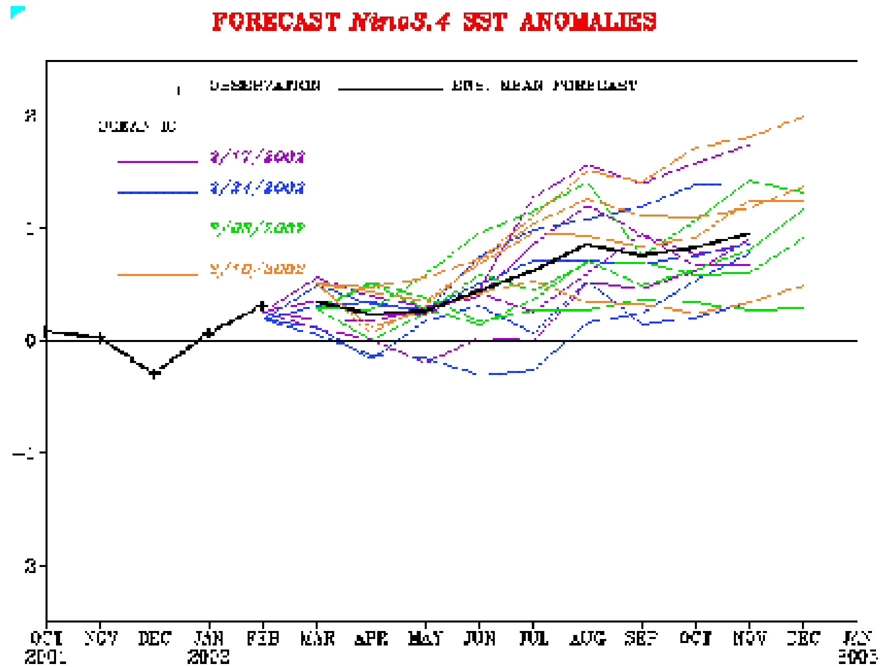
Example: North American Ensemble Forecast System (NAEFS)

CURRENT NWS PRACTICE

2) "CLIMATE" ENSEMBLE:

a) 12–months coupled ocean–atm fcsts

b) Average the SST fcsts



c) Run AGCM ensemble forced by average SST fcst

STRENGTH:

Ensemble approach used both for coupled and AGCM model fcsts for enhancing (weak) signal

SHORTCOMINGS:

a) Coupled ensemble (lagged fcst) perturbations not optimal

b) Uncertainty information related to SST fcst is discarded

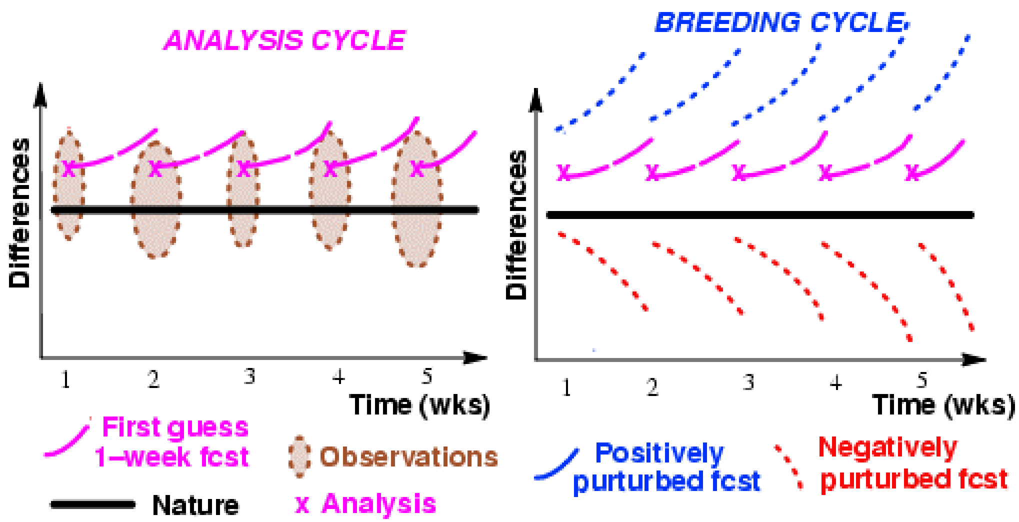
c) Initial condition information from atmosphere not used

3) POSSIBLE FUTURE SYSTEM:

"WEATHER *AND* CLIMATE" ENSEMBLE?

COUPLED MODEL ENSEMBLE –

Use dynamically constructed perturbations



Toth and Kalnay 1996

a) *Nonlinear bred perturbations capture dominant ENSO instability*

b) *Initial error present in analysis dominated by same instability*

c) *Symmetrically placed perturbed fcsts provide optimal ensemble*

AGCM ENSEMBLE – PART OF COUPLED SYSTEM?

i) Use ensemble SST fcsts as various boundary scenarios

ii) Single set of AGCM fcsts for all time ranges *(D1–climate)*

ONE–TIER SYSTEM – If possible, with coupled ocean model

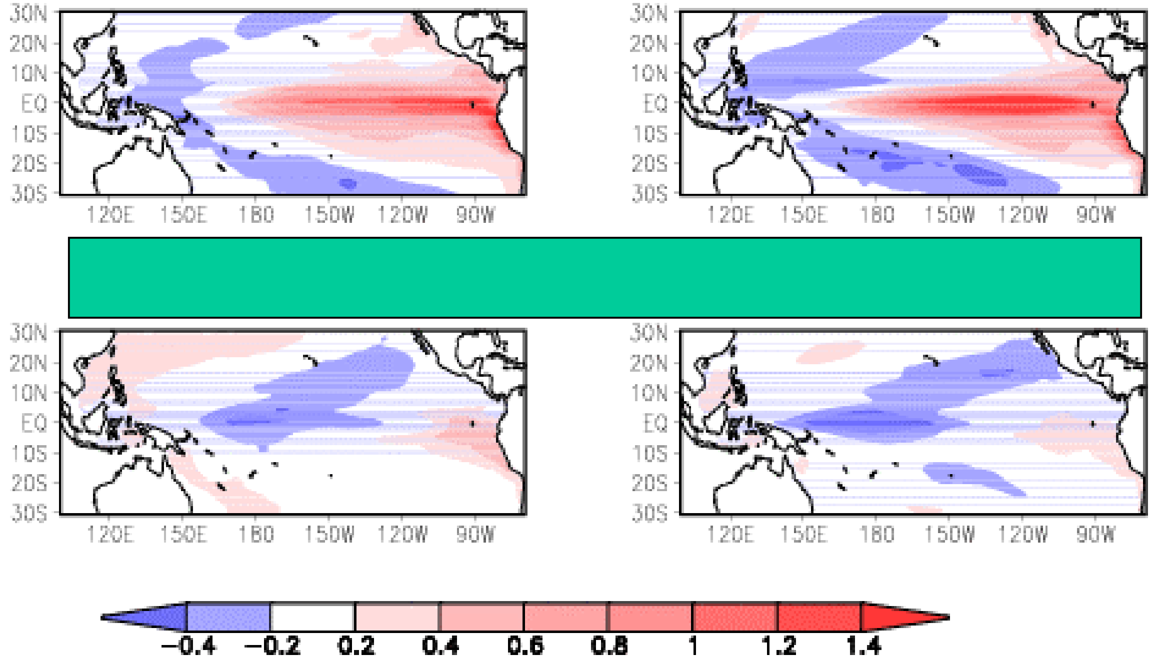
NEW NCEP COUPLED MODEL

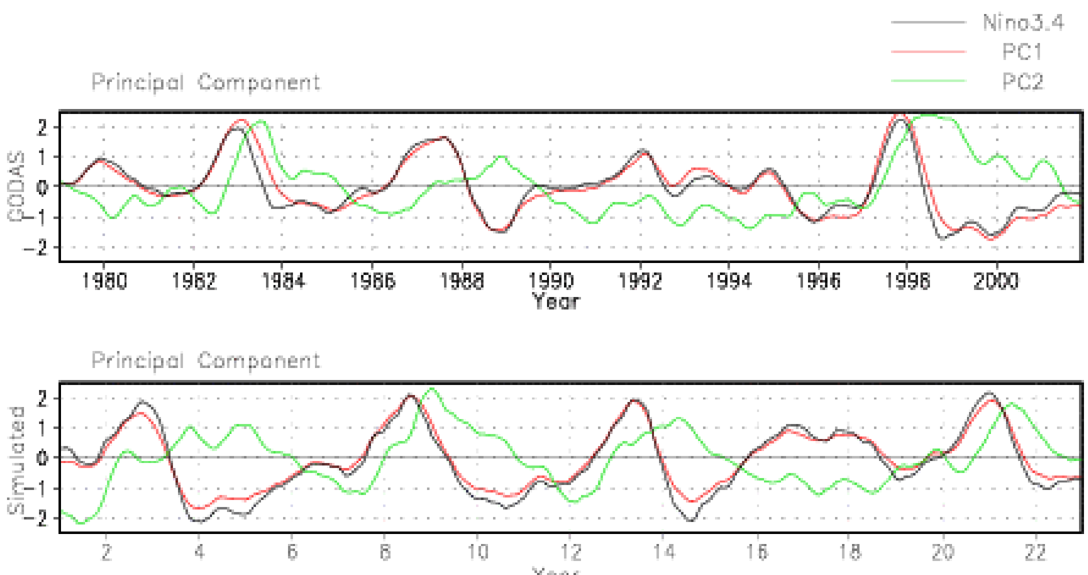
T62L64 AGCM + modified MOM3

J. Wang et al.

EOF1

EOF2





NEW NCEP COUPLED MODEL

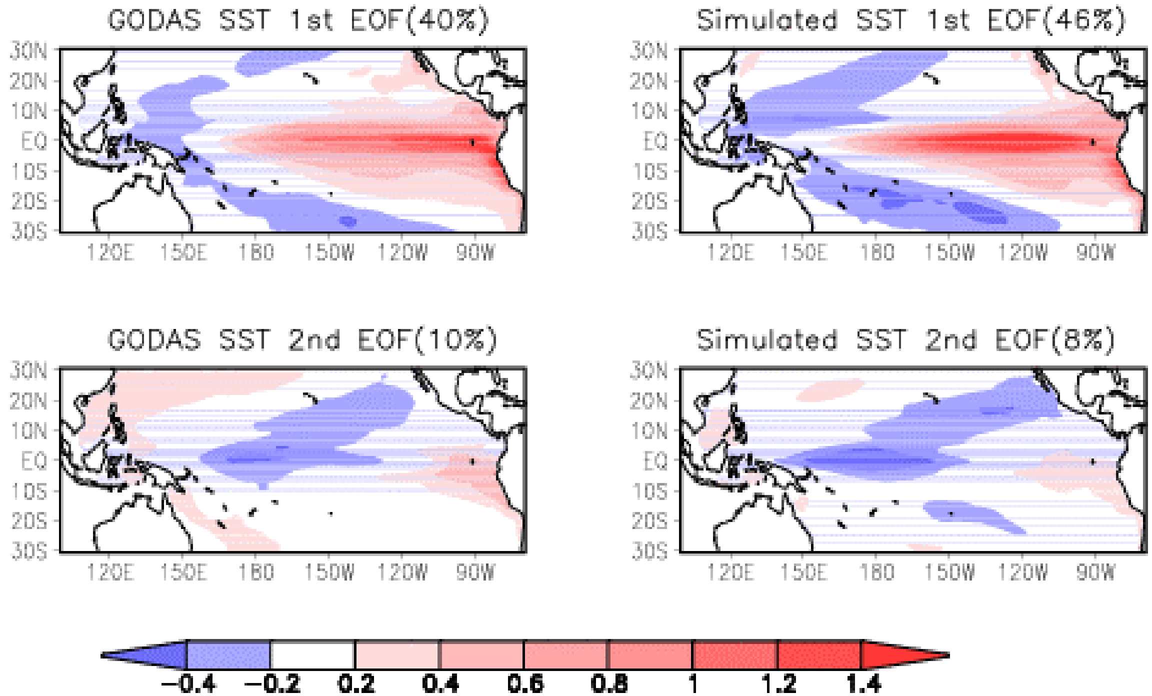
T62L64 AGCM + modified MOM3

J. Wang et al.

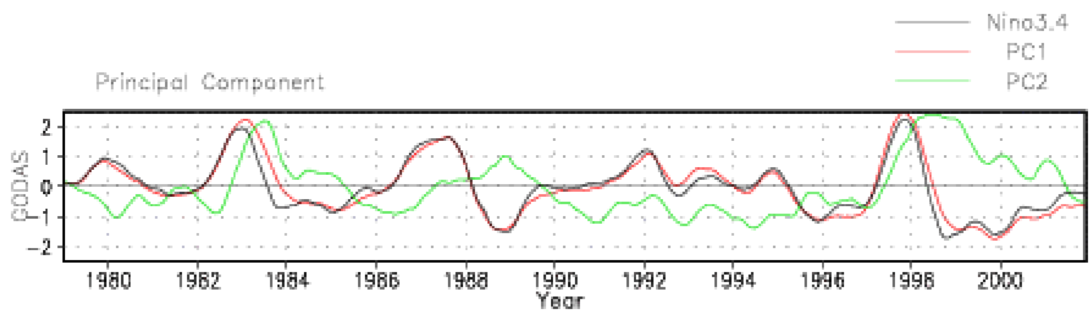
SIMULATED **ANALYZED**

EOF1

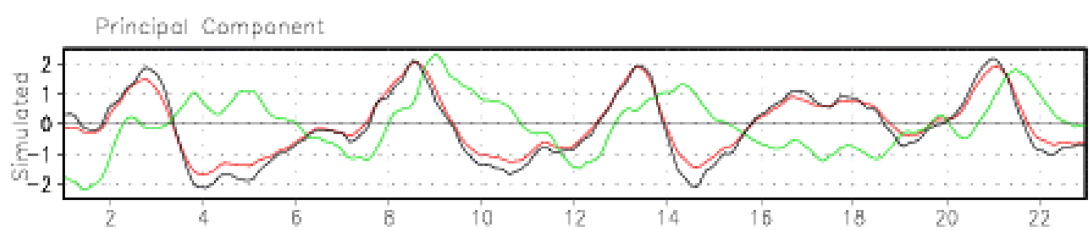
EOF2



ANALYZED



SIMULATED

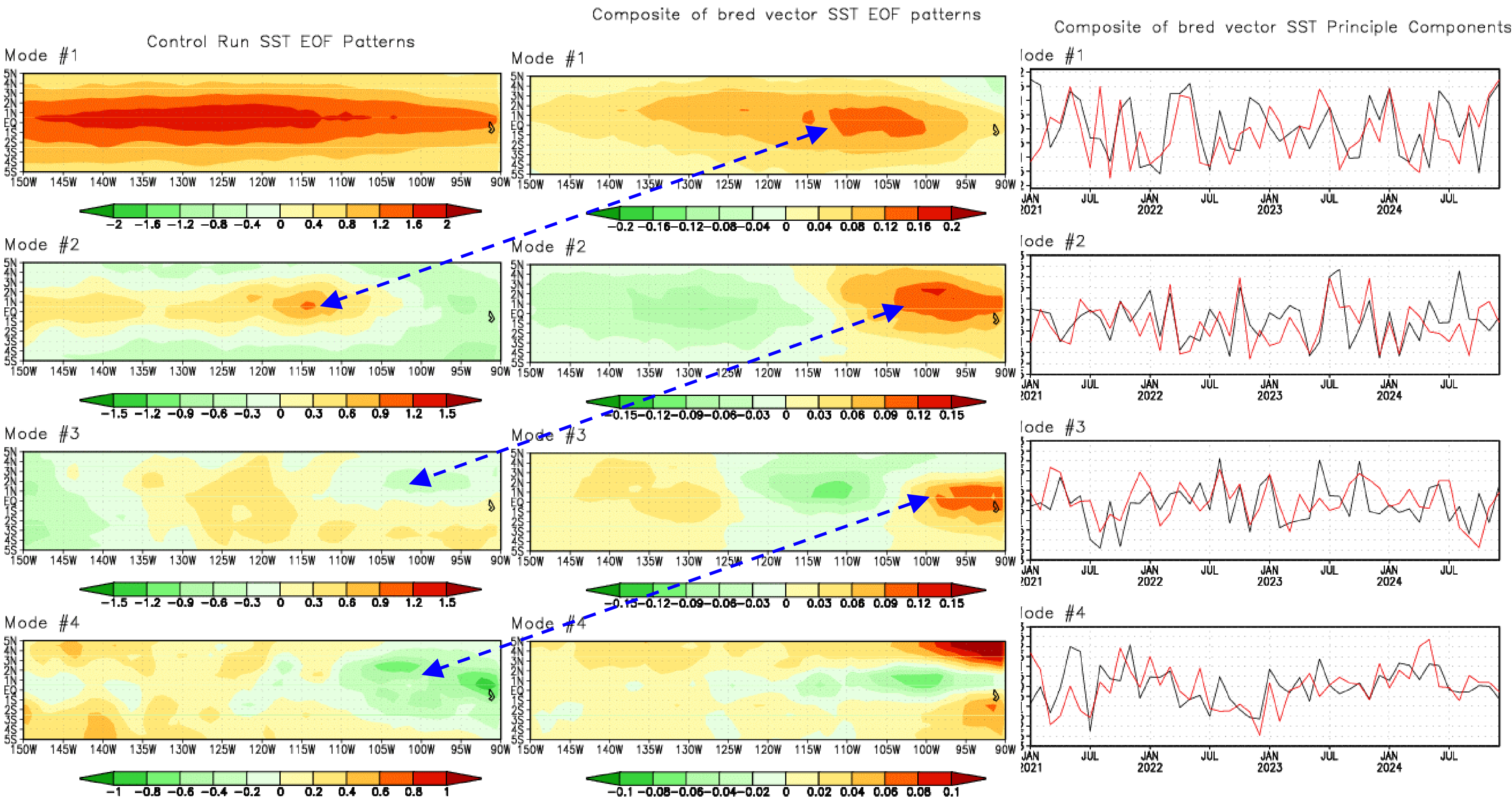


PREDICTABILITY EXPERIMENTS WITH COUPLED MODEL G. Yuan

EOFs of long model run
Simulated ENSO variab.

EOFs of bred vectors
Instabilities (at gradients)

EOF timeseries of 2 BVs
~3-4 degrees of freedom



NCEP SHORT-RANGE ENSEMBLE FORECAST SYSTEM (SREF)

J. McQueen, J. Du, B. Zhou, B. Ferrier

OPERATIONAL SYSTEM

- 15 Members out to 63 hrs
- 2 versions of ETA & RSM
- 09 & 21 UTC initialization
- NA domain
- 48 km resolution
- Bred initial perturbations
- Products (on web):
  - Ens. Mean & spread
  - Spaghetti
  - Probabilities
  - Aviation specific
- Ongoing training

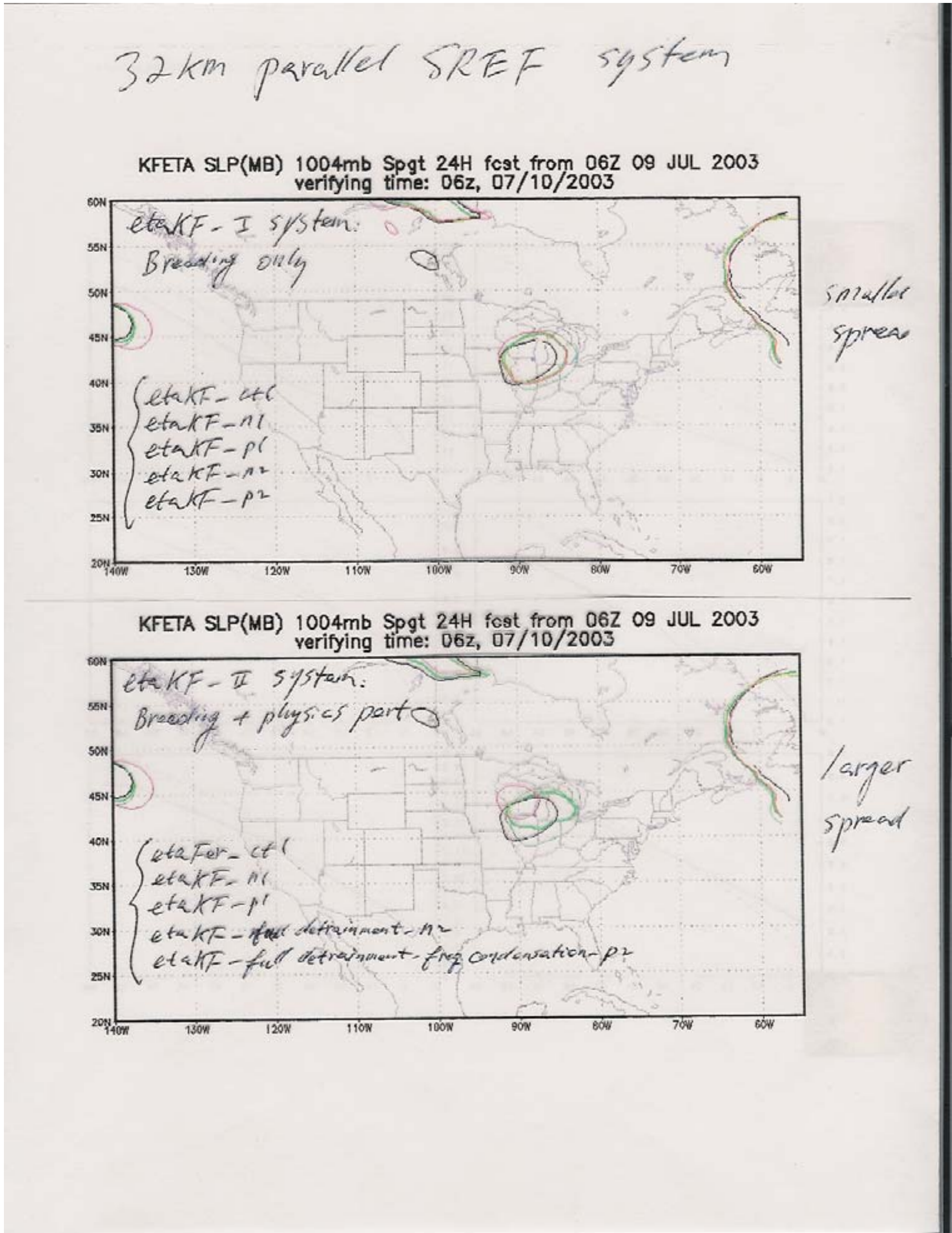
PLANS

- *More model diversity - 5+2 model versions*
- *4 cycles per day (3&15 UTC)*
- *32 km resolution*
- *New products*
  - *Aviation*
  - *AWIPS*
  - *Winter Weather Exper.*
- *Transition to WRF*

NCEP SHORT-RANGE ENSEMBLE FORECAST SYSTEM (SREF) J. Du

Parallel SREF Systems (32km)

IC ensemble (SREF_I)		*physics ensemble (SREF_II)*
eta_bmj_ctl	-->	same
eta_bmj_n1	-->	same
eta_bmj_p1	-->	same
eta_bmj_n2	-->	**eta_ras_n2**
eta_bmj_p2	-->	**eta_ras.mic_p2**
rsm_sas_ctl	-->	same
rsm_sas_n1	-->	same
rsm_sas_p1	-->	same
rsm_sas_n2	-->	**rsm_ras_n2**
rsm_sas_p2	-->	**rsm_ras_p2**
eta_kf_ctl	-->	**eta_Fer_ctl**
eta_kf_n1	-->	same
eta_kf_p1	-->	same
eta_kf_n2	-->	**eta_kf_fulldetr_n2**
eta_kf_p2	-->	**eta_kf_fulldetr.freqcon_p2**



How WSR targeting happens…

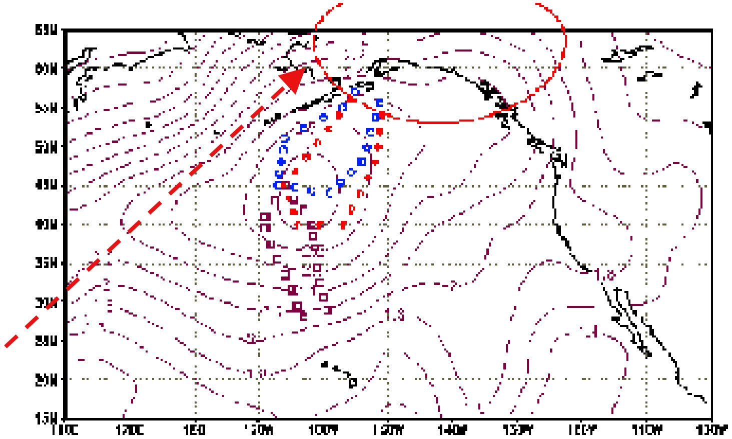
1. **Targeting cases selected** in areas where critical winter weather events with high forecast uncertainty may have a potentially large societal impact.
2. **Sensitivity calculations** performed using ETKF, and a **decision** is made (flight/no flight).
3. **Observations** are taken and used in operational analysis and forecast products by major NWP centers.
4. **Verification** is performed by comparing operational analyses/forecasts including the targeted data with analyses/forecasts excluding the targeted data.

WSR03 EXAMPLE

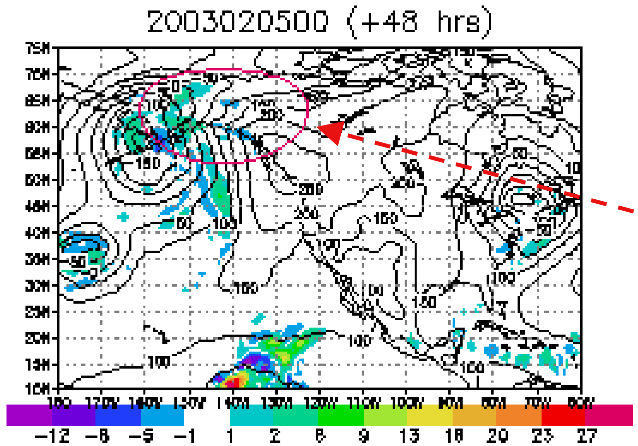
L. Holland, S. Majumdar, J. Moskaitis

HIGH PRIORITY FLIGHT REQUEST
Alaska heavy precipitation event
Observation time: 03020300
Verification Time: 03020500
Lat: 62N
Lon: 142W

SENSITIVE AREA,
Suggested flight tracks

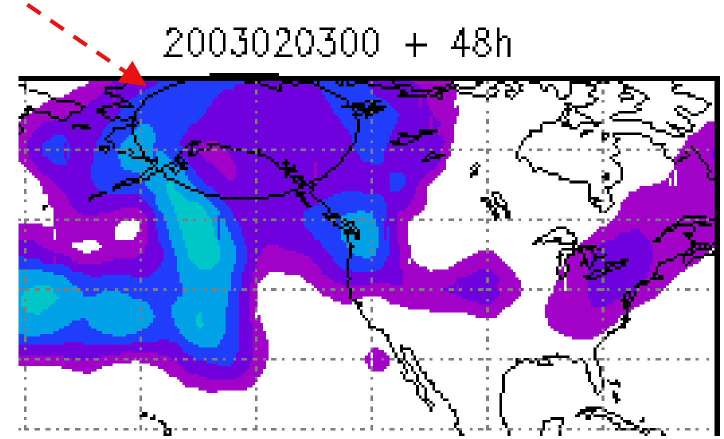


ACTUAL DATA IMPACT, PRECIP

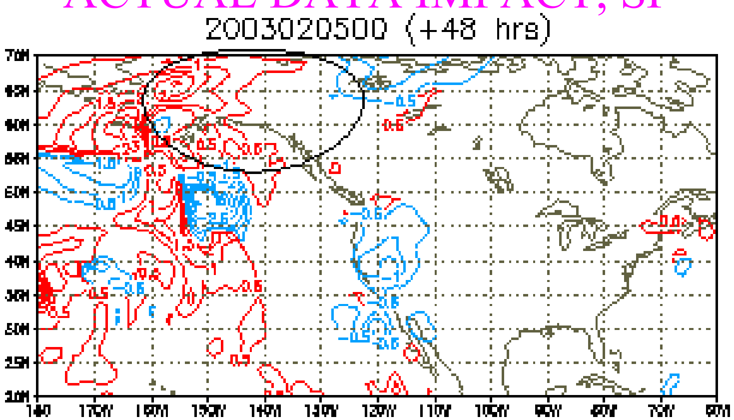


Verification region

PREDICTED DATA IMPACT
Winds at 850, 500, 250



ACTUAL DATA IMPACT, SP



Forecast
improvement
vs.
degradation

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FCST UNCERTAINTY

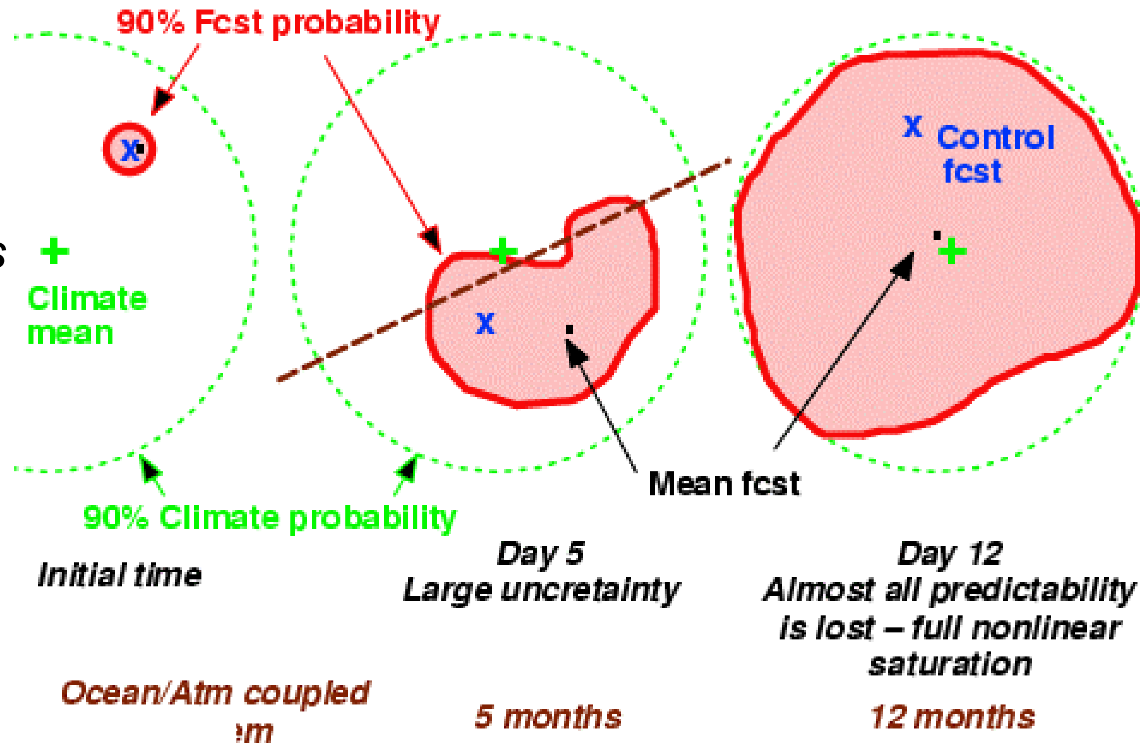
1) The atmosphere is a **deterministic system** *AND* has at least one direction in which **perturbations grow**

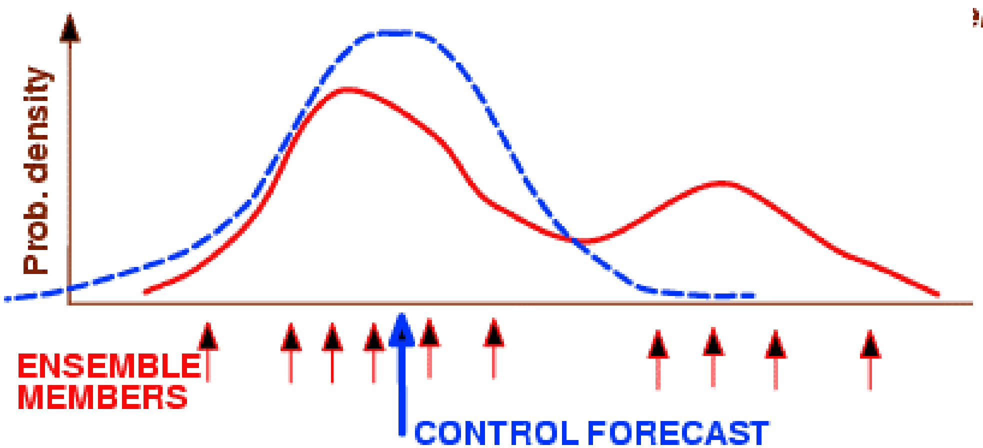
2) **Initial** state (and model) has **error** in it ==>

Chaotic system + Initial error =(Loss of) Predictability

Is it only information from Mean and spread in ensemble That matters?

Or higher moments / further details Also matter?





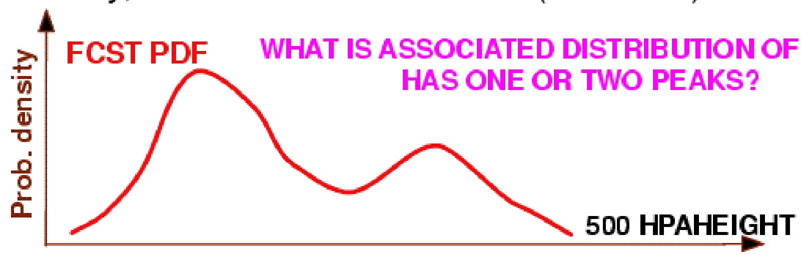
COMPARING SINGLE CONTROL & ENSEMBLE FCSTS

1) Expected value: Ensemble mean better than control?
2) *More detailed pdf from ensemble (m vs. 1 members)?*
3) *Case dependent variations in spread: Ensemble has skill?*
4) **Is it only 2nd moment (spread), or further details in ensemble?**

CAN ENSEMBLES SKILLFULLY PREDICT BIMODALITY?

W O R K   I N   P R O G R E S S

Difficult to verify, **NEEDS LOTS OF DATA** (too much)

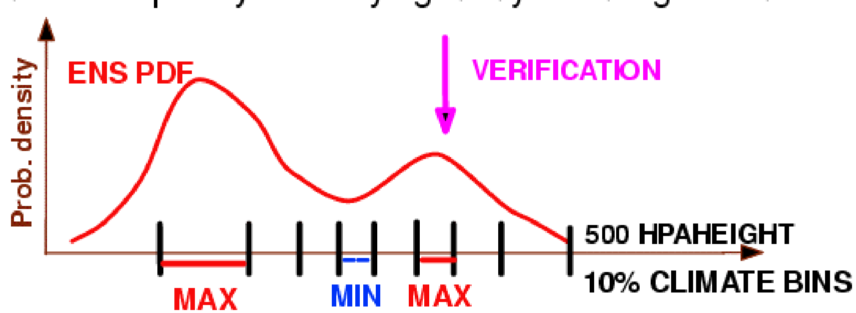


Each fcst pdf pattern needs large number of realizations
to establish associated distribution of observations

APPROACH:

Use climate pdf as reference (10 climatologically equally likely bins)
Drastically reduce dof by compositing pdf according to location of max

1) Identify bimodal distributions wrt climate pdf
2) Locate local maxima & minima in terms of 10 climate bins
3) Establish frequency of verifying analysis falling in max/min bins



CAN ENSEMBLES SKILLFULLY PREDICT BIMODALITY?

1) Given overall ensemble fcst distribution –

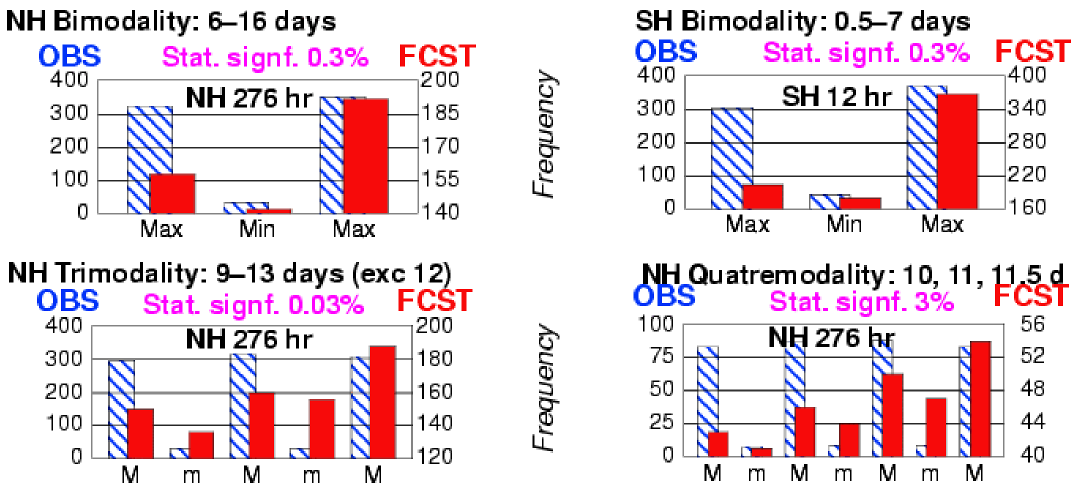
Does bimodality occur more frequently than expected by chance?

Ratio between multi/unimodal fcst pdfs	*12*	*168*	*288*	*360h*
NH	0.12	1.1	12	23
SH	0.93	5.3	14	17

Many bimodal pdfs must be due to sampling; have not tested stat. signif

2) ***In bimodal fcst cases, do obs confirm bimodality?***

COMPOSITE RESULTS for NH & SH extratr. for Nov 2000–Feb 2001



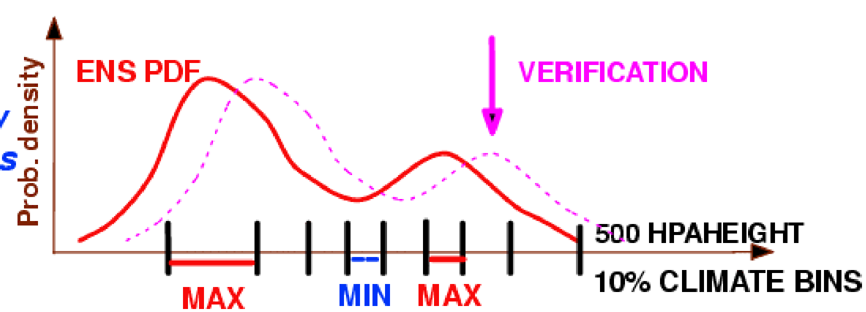
BLUE - FCST

RED - OBS

PROBLEMS:

Bias in fcst model seriously hinders analysis

Bin–resolution (10) too coarse at short lead



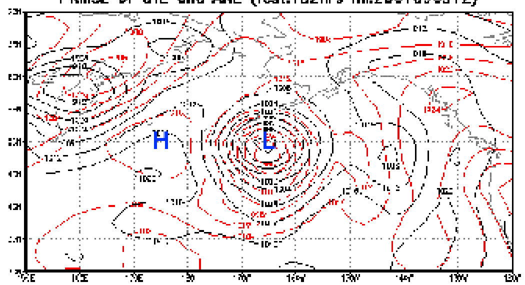
EXPECTATION: Verification of bias–reduced fcsts will show stronger multimodal behavior

CAN ENSEMBLES SKILLFULLY PREDICT BIMODALITY?

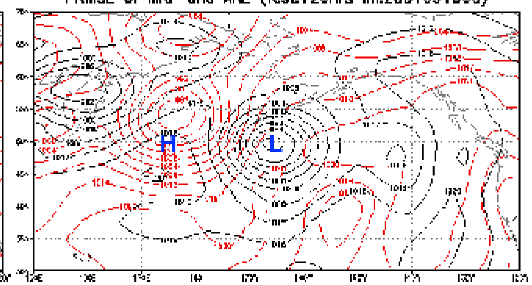
4) **Does multimodality as described here have fcst implications?**

CASE STUDY OF LARGE VARIATIONS IN CONSECUTIVE CONTROL FCSTS

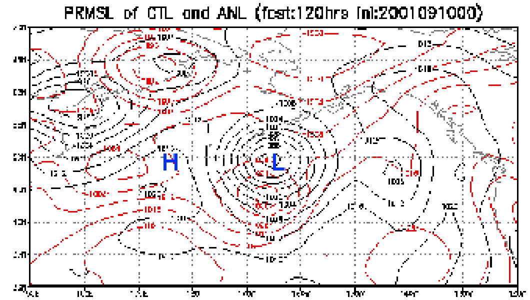
PRMSL of CTL and ANL (fcst:132hrs ini:2001090912)



PRMSL of MRF and ANL (fcst:120hrs ini:2001091000)



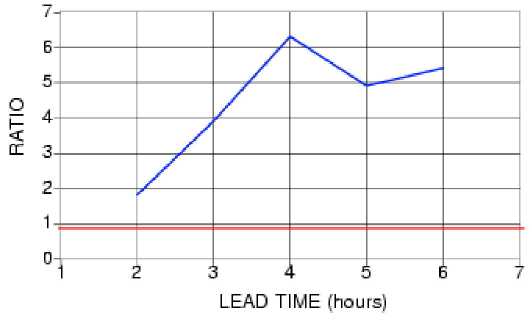
PRMSL of CTL and ANL (fcst:120hrs ini:2001091000)



IS THIS PERHAPS RELATED TO MULTIMODALITY?

USE 50–MEMBER TIME–LAGGED ENSEMBLE

initialized 0909 & 0910 00 &12Z, 0911 00Z

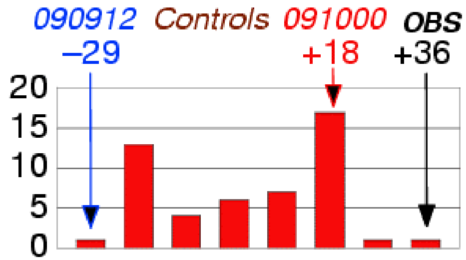


a) # bimodal gridpoints vs average # for Sept 2001 (Ratio)

NUMBER OF MULTIMODAL GRIDPOINTS MUCH HIGHER THAN USUAL

Difference in ratio significant? Probably yes (have not checked)

CASE STUDY OF LARGE VARIATIONS IN CONSECUTIVE CONTROL FORECASTS



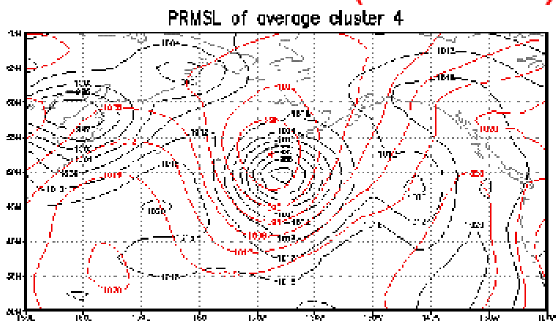
Distribution of High–Low MSLP difference

STRONGLY BIMODAL

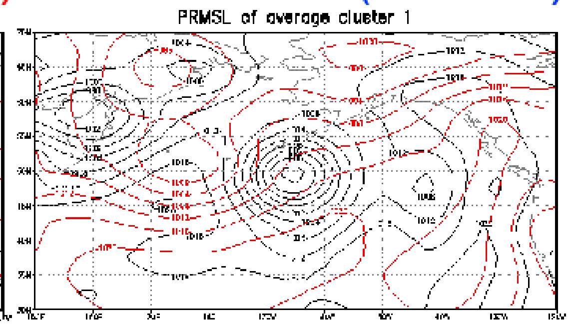
Statistically significant? Have not tested

CLUSTER ANALYSIS – ***Two dominant patterns***

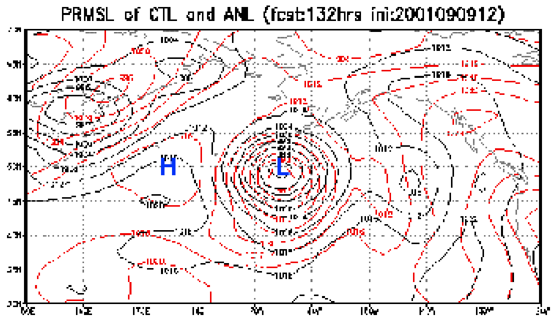
GOOD CLUSTER (19 members)



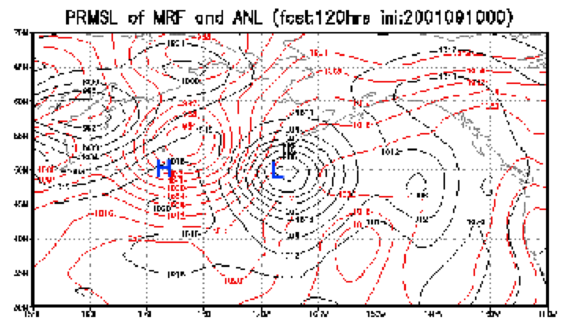
BAD CLUSTER (20 members)



GOOD CONTROL FCST



BAD CONTROL FCST



CAN CASES LIKE THIS

BE IDENTIFIED BY STAT METHODS AS LIKELY REAL?

OUTLINE / SUMMARY

- **DEFINITION OF PREDICTABILITY**
  - No universally accepted form?
- **COMPLEX MEASURE OF PREDICTABILITY**
  - What is predictable (Probabilistic forecast format)
  - Forecast skill (Resolution)
- **PREDICTING PREDICTABILITY**
  - Practical aspect (Dynamical-statistical error variance prediction)
  - Theoretical aspect (Predictability depends on our ever expanding knowledge)
- **HOW PREDICTABILITY CAN BE ENHANCED?**
  - Capture flow dependent variations in predictability
  - Use “high resolution” forecast in probability space
  - Consider details in pdf (Bimodality)
- **POSSIBLE FUTURE ENHANCEMENTS**
  - **CAPTURE MODEL RELATED FLUCTUATIONS IN FORECAST UNCERTAINTY**
  - Represent model errors due to
    - Structural
    - Parametric
    - Closure type uncertainties
  - ***NEED (COSTLY AND) COMPREHENSIVE APPROACH?***

SUMMARY

PREDICTABILITY (RESOLUTION) IS ENHANCED WHEN

- **Flow dependent fluctuations in uncertainty** captured
  - Ensemble mode vs. control forecast
  - Stronger effect at longer lead times

- **Detailed** (and not bivariate) **probability distribution** is used
  - Stronger effect at shorter lead times
  - Only broad features of pdf, or details also matter?
    - **Bi- and multimodality** appears to contribute to ensemble skill

NCEP ENSEMBLE REPRESENTS ONLY INITIAL VALUE RELATED UNCERTAINTY

CAN VARIATIONS IN FORECAST UNCERTAINTY DUE TO MODEL IMPERFECTNESS BE ALSO CAPTURED?

WOULD THIS LEAD TO ENHANCED PREDICTABILITY?

- Lower ensemble mean rms error?
- Increased resolution (use of more close to 0 and 100% fcst probability values)?
- Details in pdf more trustworthy?

MODEL RELATED FORECAST UNCERTNAINTY

SOURCES OF UNCERTAINTY - *MODELS ARE IMPERFECT*:

- Structural uncertainty (eg, choice of structure of convective scheme)
- Parametric uncertainty (eg, critical values in parameterization schemes)
- Closure/truncation errors (temporal/spatial resolution; spatial coverage, etc)

NOTES:

- Two main sources of forecast errors hard to separate =>
- Very little information is available on model related errors
  - Tendency to attribute all forecast errors to model problems

REPRESENTING MODEL RELATED FORECAST UNCERTAINTY -

NO THEORETICALLY SATISFYING APPROACH

- Change structure of model (eg, use different convective schemes, etc, MSC)
- Add stochastic noise (eg, perturb diabatic forcing, ECMWF)
- Works? Advantages of various approaches need to be carefully assessed
  - Are flow dependent variations in uncertainty captured?
  - Can statistical post-processing replicate use of various methods?
- Need for a
  - more comprehensive and
  - theoretically appealing approach

LOTS OF WORK, & POTENTIAL?

WHAT IS PREDICTABILITY? AND FORECASTING?

DISCUSSION AT SEPT. 2002 ECMWF WORKSHOP –

No generally accepted, clear definition?

- Shukla:
  - Predictability – Just talking about things, without really doing it, theory
  - Forecasting – The REAL thing, telling what's going to happen
- Palmer:
  - Predictability – Has practical aspect, probabilistic forecasting, link with users
- Webster:
  - Predictability – Explore what can be skillfully predicted
- Simple measures of predictability:
  - Linear –
    - Global or local Lyapunov Vectors/Exponents (LVs)
    - Finite-Time Normal Modes (FTNM, Frederiksen & Wei)
    - Singular vectors (SVs)
  - Nonlinear -
    - Bred vectors (Nonlinear LVs)
    - Nonlinear SVs, etc

WHAT IS PREDICTABILITY?
WHAT IS FORECASTING?

PREDICTABILITY - STUDYING WHAT IS PREDICTABLE

***BASED ON TWO FACTORS*:**

INHERENT NATURE OF FLOW

Theoretical approach – Have to make oversimplifying assumptions (see measures)
Provides general information, limited insight

KNOWLEDGE / REPRESENTATION OF

Initial state of system
Laws governing evolution of system

Practical approach – Tell every day what is *Predictable?*
Expected error?
Forecast uncertainty? =>

PROBABILISTIC FORECASTING

FORECASTING, IN ITS FULL SENSE, IS
PROBABILISTIC, WITH CASE SPECIFIC PREDICTABILITY INFORMATION =>
ASSESSMENT OF PREDICTABILITY IS PART OF FORECASTING

"NO FORECAST IS COMPLETE UNLESS PROVIDED IN PROBABILISTIC FORMAT"

EXTRA INFORMATION FOR USERS?

"PREDICTING PREDICTABILITY"?

Don't know what organizers had in mind…

PRACTICAL INTERPRETATION:

Given **current** probability forecast AND distribution of observing locations at **future** time

Predict how forecast uncertainty will change

Dynamical-statistical methods

APPLICATION – Targeted observations (Bishop et al., Berliner et al.)

THEORETICAL INTERPRETATION:

Predictability is strongly linked with forecasting and depends on our knowledge of:

Initial conditions

Governing equations

Given **current** level of predictability, and expected advances that lead to **future** observing, data assimilation, and forecast systems –

Predict how predictability will change in 50 (100) years

Can't do this – Instead:

APPROACH: **Look at predictability using different existing forecast methods**

Assess how improvements contribute to enhanced predictability

Speculate what advances can be expected

PHILOSOPHICAL ASPECT –

PREDICTABILITY DEPENDS ON OUR UNDERSTANDING OF NATURE

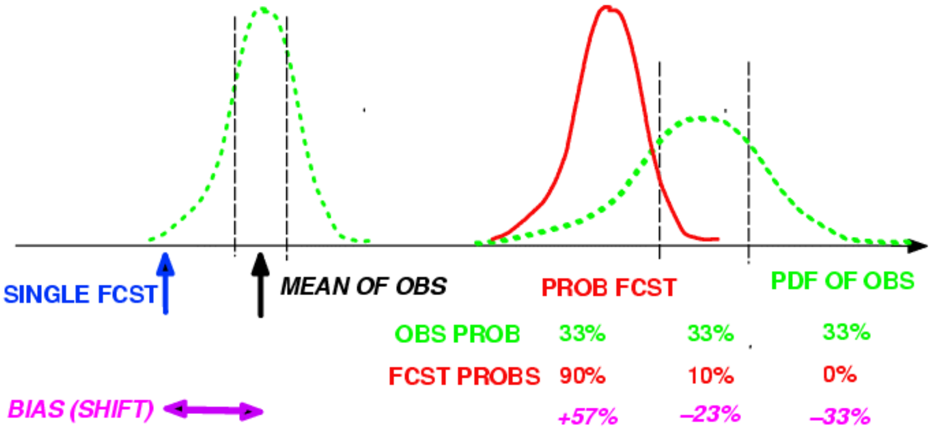
HOW TO MEASURE PREDICTABILITY?

USE FORECAST SKILL MEASURES

Assume perfect reliability – Skill is measured by resolution

RELIABILITY – Lack of systematic error

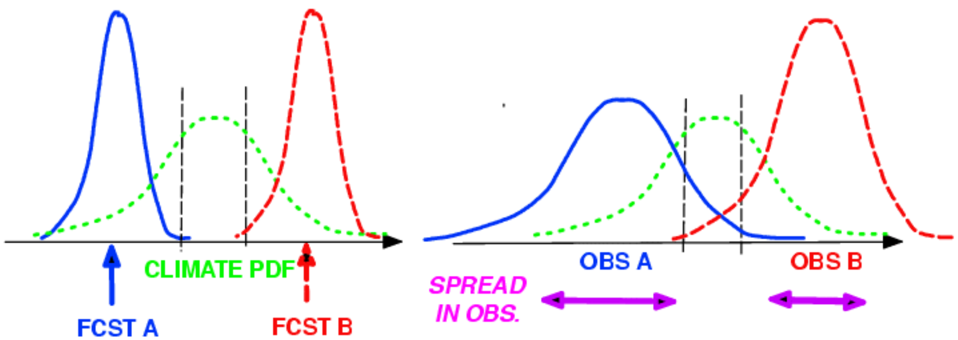
(No conditional bias)



CAN BE statistically corrected

(assuming stationary processes)

RESOLUTION – Different observations preceded by different forecasts



CANNOT be statistically corrected -

INTRINSIC VALUE OF FCST SYSTEM

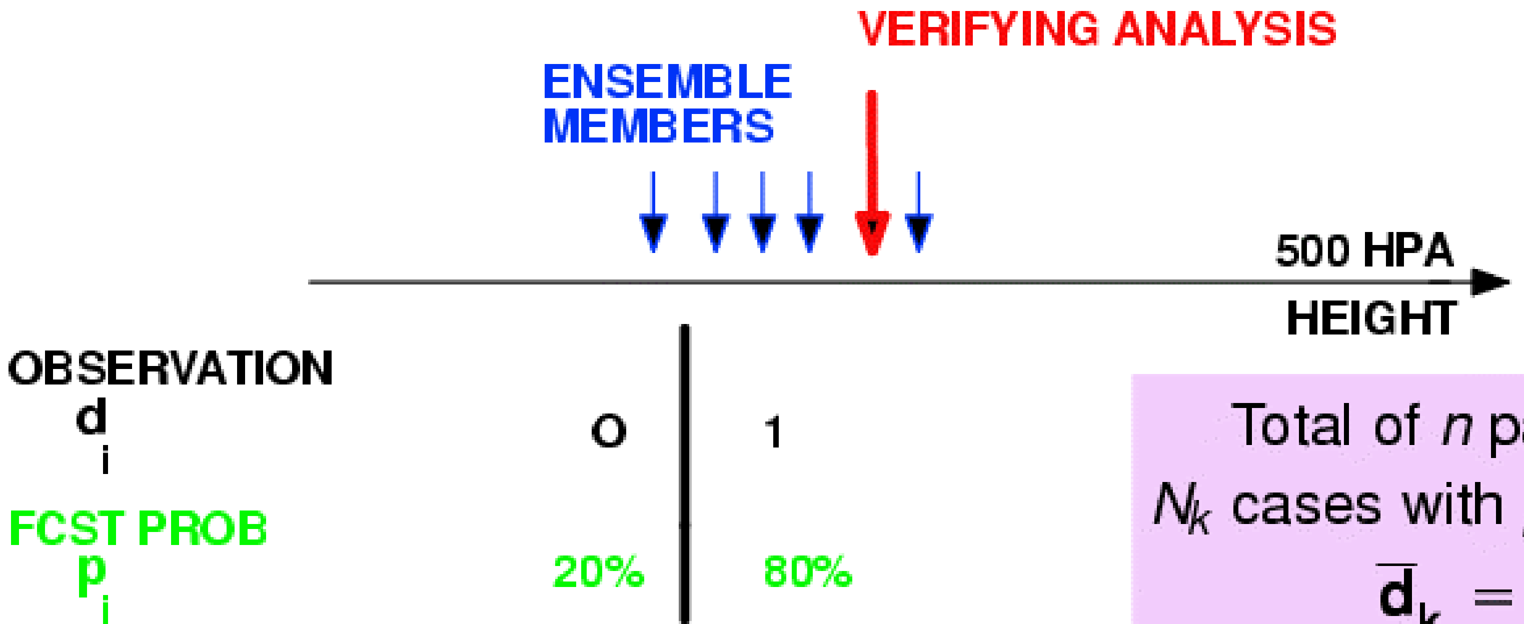
For perfectly reliable fcsts, resolution = ensemble spread = spread in observations =>

Perfect predictability = only 0 & 100% probabilities used, and always correct

No predictability = No matter what we forecast, climate distribution is observed

BRIER SCORE (BS) and BRIER SKILL SCORE (BSS)

For verifying categorical probability forecasts (event occurs or not)



Total of n pairs of cases

N_k cases with p_k probability

$$\overline{d}_k = \frac{1}{N_k} \sum_{i \in N_k} d_i$$

$$BS(p, d) = \frac{1}{n} \left[\sum_{i=1}^{n} (p_i - d_i)^2 \right]$$

$$BS = \frac{1}{n} \left[\sum_{k=1}^{K} N_k (p_k - \overline{d}_k)^2 \right] - \frac{1}{n} \left[\sum_{k=1}^{K} N_k (\overline{d}_k - \overline{d})^2 \right] + \overline{d}(1 - \overline{d})$$

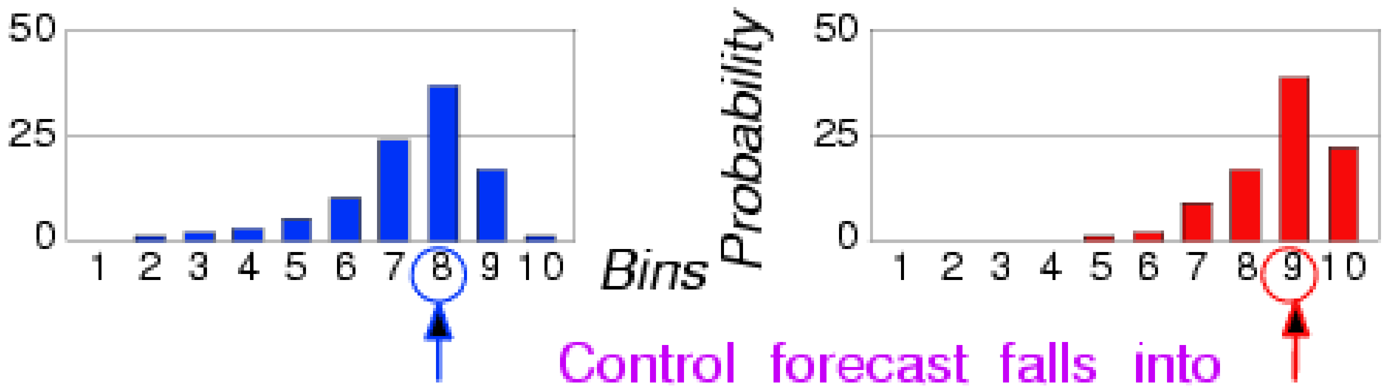
Reliability — Resolution — Uncertainty

$$BSS = 1 - \frac{BS\ (\text{forecast})}{BS\ (\text{climatology})}$$

PROBABILISTIC FORECASTING

Based on SINGLE FORECAST –

***One integration with an NWP model,* combined with past verification statistics**



- Does not contain all forecast information
- Not best estimate for future evolution of system
- ***UNCERTAINTY CAPTURED IN TIME AVERAGE SENSE -***
- **NO ESTIMATE OF CASE DEPENDENT VARIATIONS IN FCST UNCERTAINTY**

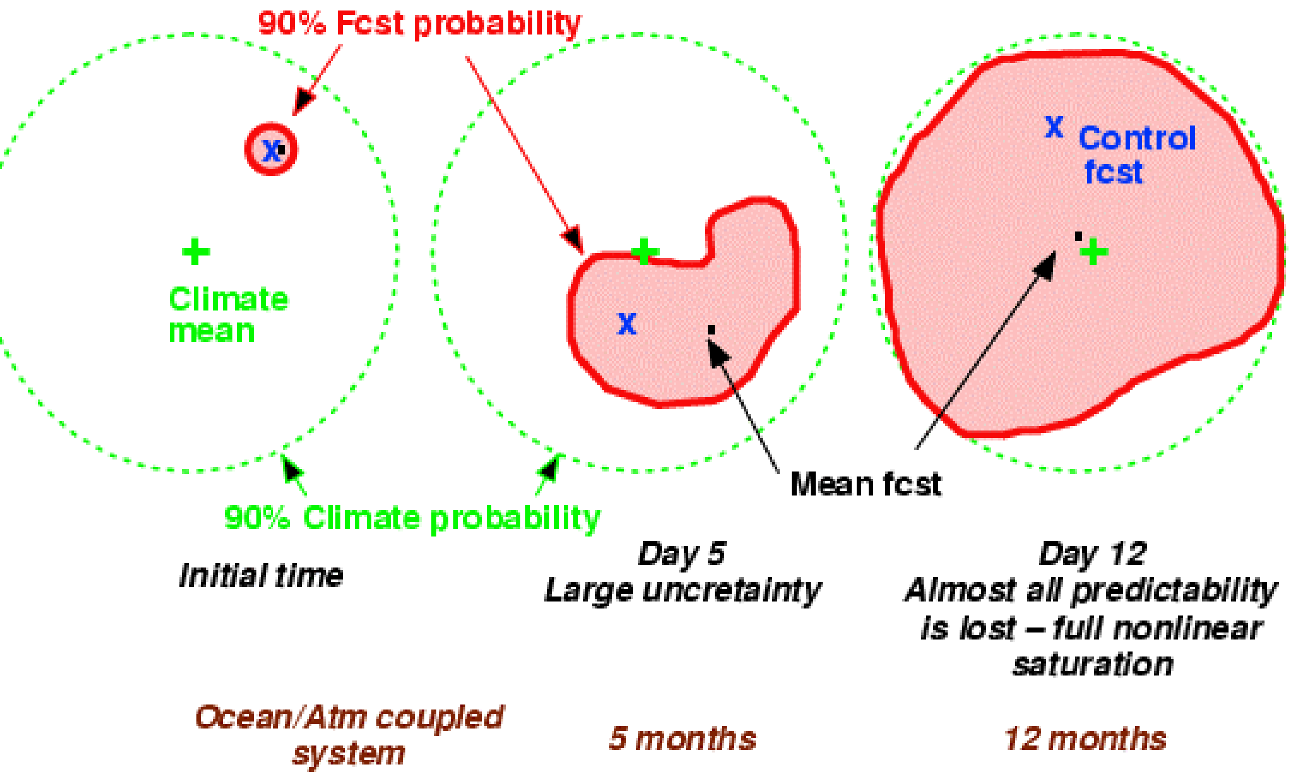
SCIENTIFIC NEEDS - DESCRIBE FORECAST UNCERTAINTY ARISING DUE TO CHAOS

ORIGIN OF FORECAST UNCERTAINTY

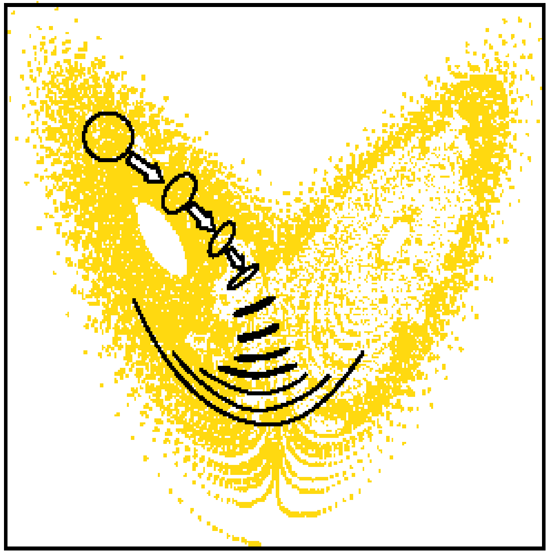
1) The atmosphere is a **deterministic system** *AND* has at least one direction in which **perturbations grow**

2) **Initial** state (and model) has **error** in it ==>

Chaotic system + Initial error =(Loss of) Predictability



Buizza 2002



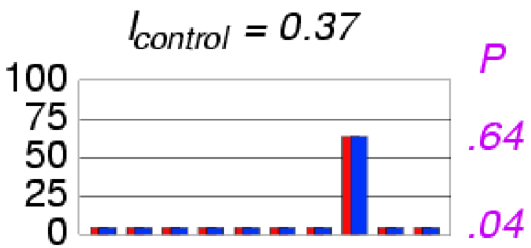
INFORMATION CONTENT

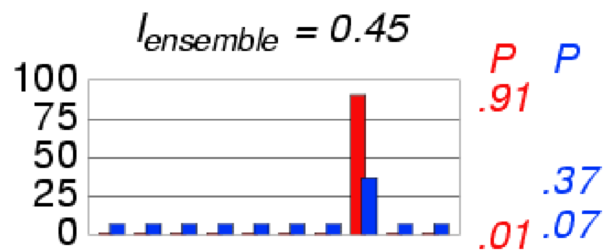
Use 10 climatologically equally likely bins to define events

$$Entropy = P\log_2 P_i$$

$$\textbf{Information in one forecast} = I = 1 - \sum_{i=1}^{10} P_i \log_{10} P_i$$

$$\textbf{Average info in n independent fcsts} = I_{ave} = \frac{1}{n}\sum_{i=1}^{n} I_i$$





Categorical control fcst can use only a fixed set of probabilities based on average reliability

Ensemble can differentiate between well and less predictable situations

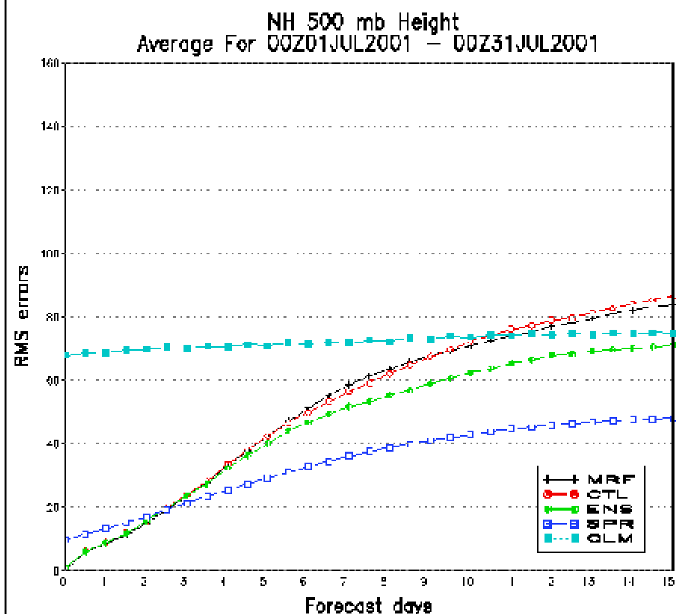
We assume that forecasts are perfectly reliable (forecast probabilities match observed frequencies)

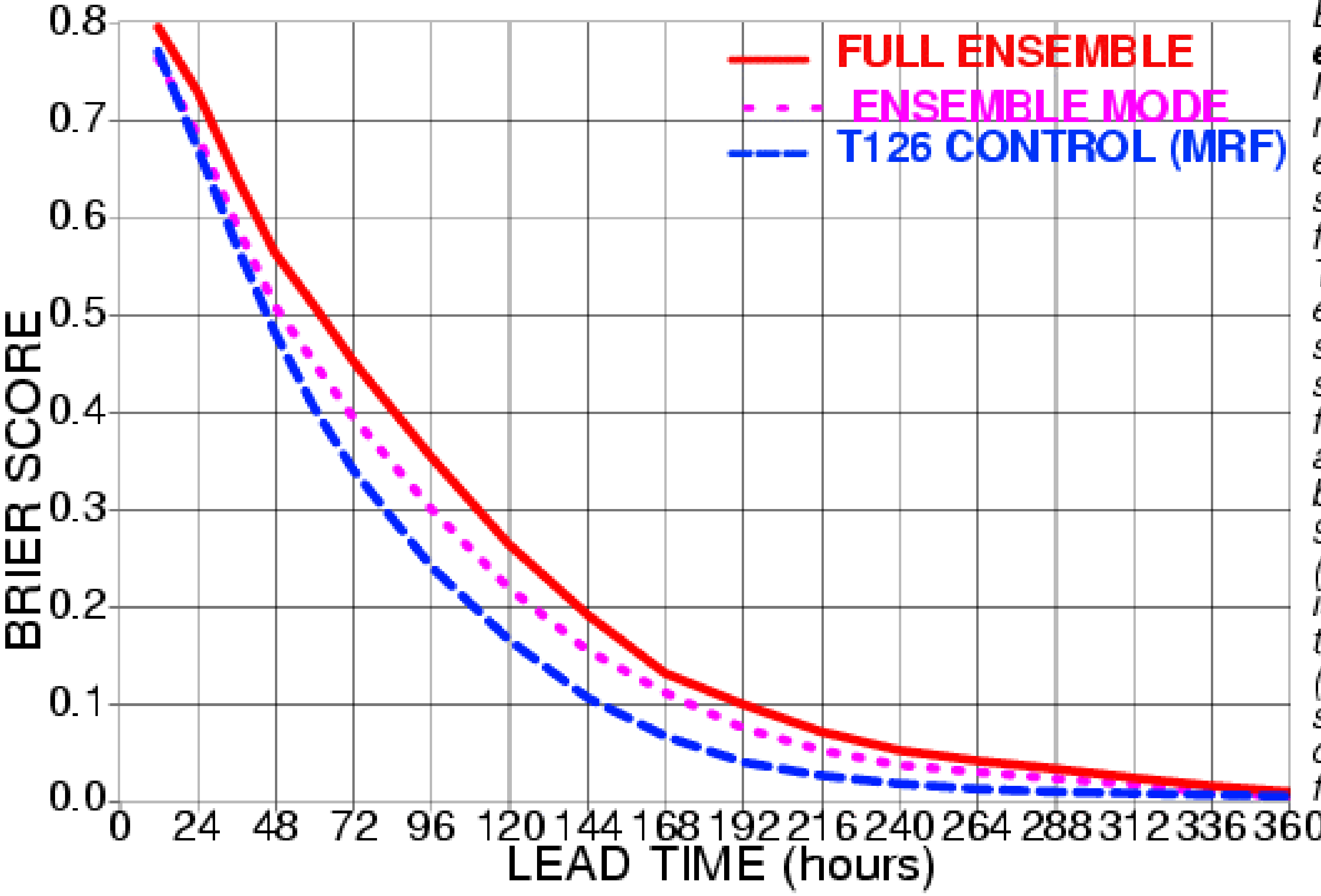
For control: Use average reliability when fcst falls/doesn't fall in a climate bin (fixed value)

For ensemble: Use average reliability for bin with most ensemble members (depends on how many fcsts fell in bin), distribute remaining probabilities equally among rest of bins

INITIAL CONDITION RELATED ERRORS

- *Sample initial errors*
- *Run ensemble of forecasts*
- *Can flow dependent variations in forecast uncertainty be captured?*
- *May be difficult or impossible to reproduce with statistical methods*





*Brier Skill Score for the **NH extratropics**, for March–May 1997. Forecasts are made for 10 climatologically equally likely bins; results shown here are the average for the two extreme bins. The bin where the control or ensemble mode falls is assigned a probability corresponding to the observed frequency of the verifying analysis falling into the same bin (P), while the remaining 9 bins are assigned (1–P)/9 (assuming perfect reliability). Note that depending on the value of the mode ($1 \leq M \leq 10$), the corresponding observed frequency for the ensemble (but not for the control) varies widely.*

RESOLUTION OF ENSEMBLE BASED PROB. FCSTS

QUESTION:

What are the typical **variations in foreseeable forecast uncertainty?**

What variations in predictability can the ensemble resolve?

METHOD:

Ensemble mode value to distinguish high/low predictability cases

Stratify cases according to ensemble mode value –

Use 10–15% of cases when ensemble is highest/loewest

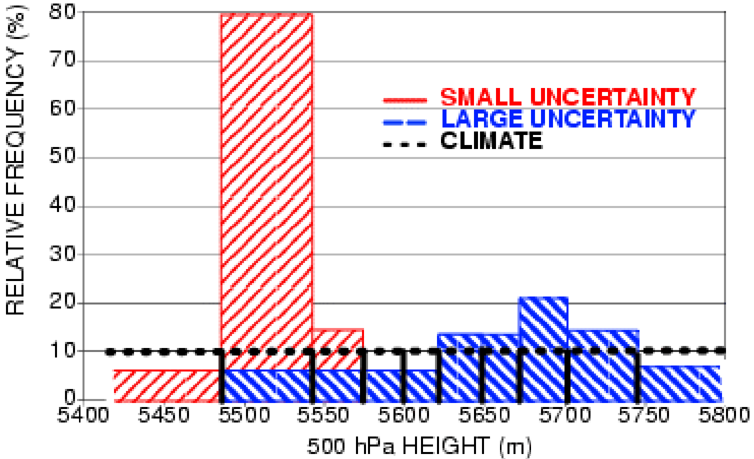
DATA:

NCEP **500 hPa NH extratropical ensemble fcsts** for March–May 1997

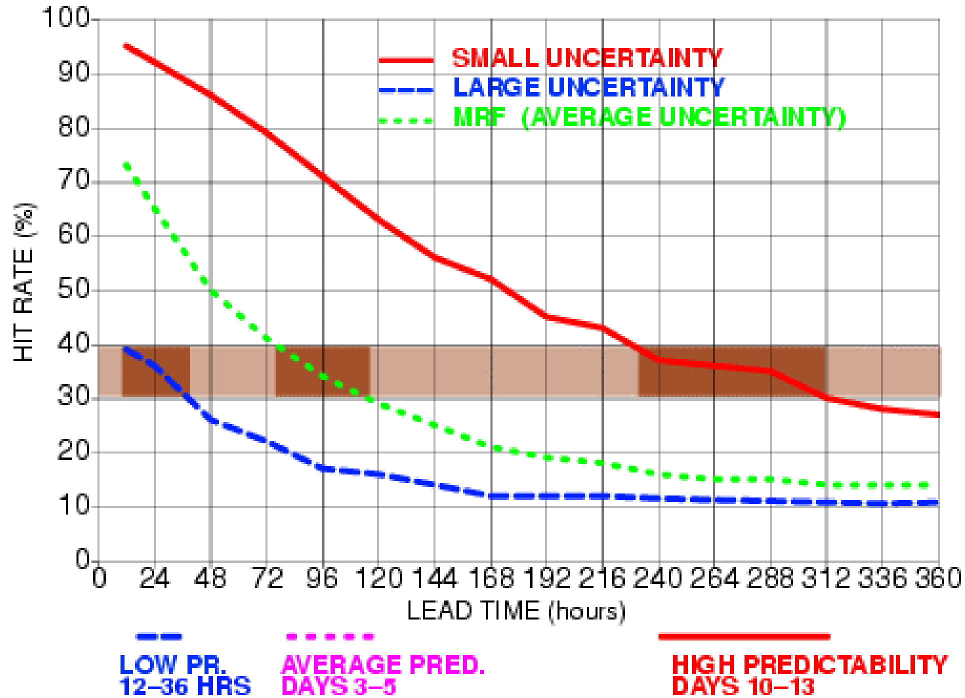
14 perturbed fcsts and high resolution control

VERIFICATION:

Hit rate for ensemble mode and hires control fcst



SEPARATING HIGH VS. LOW UNCERTAINTY FCSTS



*THE **UNCERTAINTY OF FCSTS** CAN BE **QUANTIFIED IN ADVANCE***

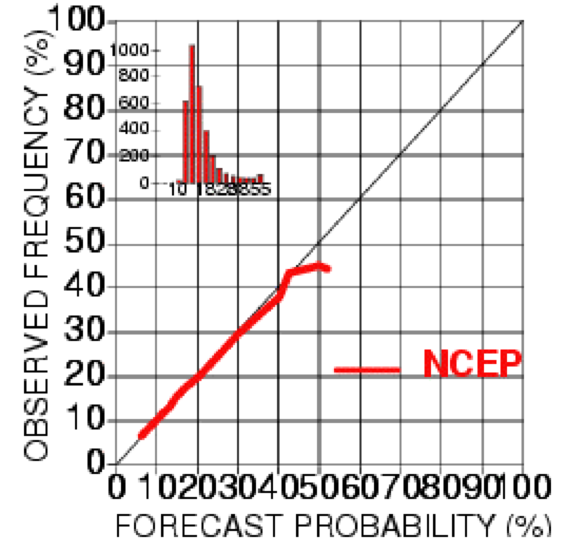
HIT RATES FOR 1–DAY FCSTS

*CAN BE **AS LOW AS 36%**, OR **AS HIGH AS 92%***

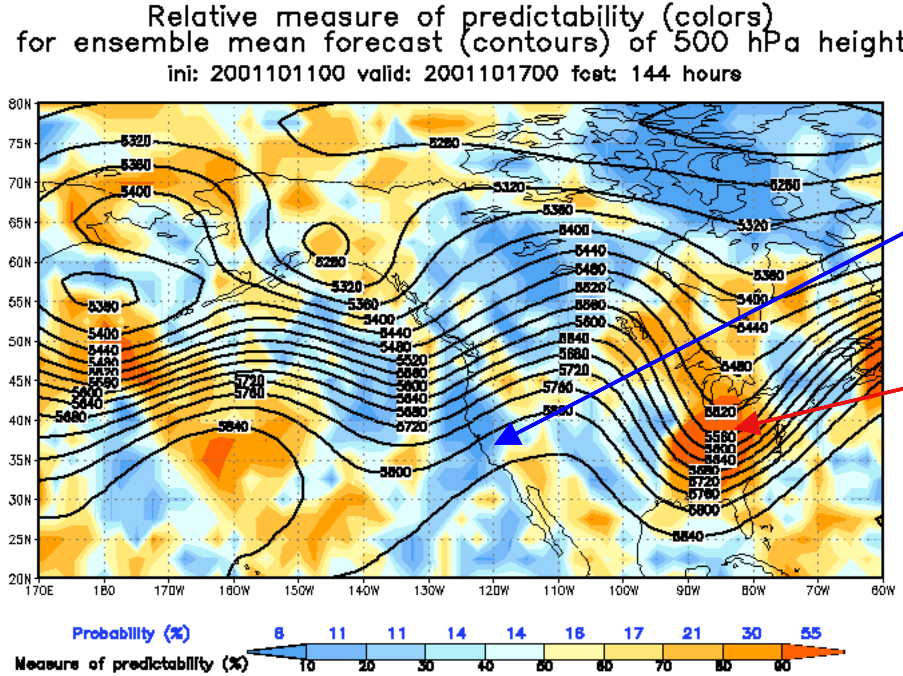
10–15% OF THE TIME A 12–DAY FCST CAN BE AS GOOD, OR A 1–DAY FCST CAN BE AS POOR AS AN AVERAGE 4–DAY FCAST

1–2% OF ALL DAYS THE 12–DAY FCST CAN BE MADE WITH MORE CONFIDENCE THAN THE 1–DAY FCST

AVERAGE HIT RATE FOR EXTENDED–RANGE FCSTS IS LOW –
VALUE IS IN KNOWING WHEN FCST IS RELIABLE



Reliability diagram for 240–hour lead time 500 hPa height NH extratropics forecasts between March and May 1997. Forecast probabilities are based on how many ensemble members fell in any of 10 climatologically equally likely bins at each gridpoint, and are calibrated using verification statistics from the winter of 1995–96. Insert in upper left corner shows in how many events a particular forecast probability was used for the most likely bin (ensemble mode).

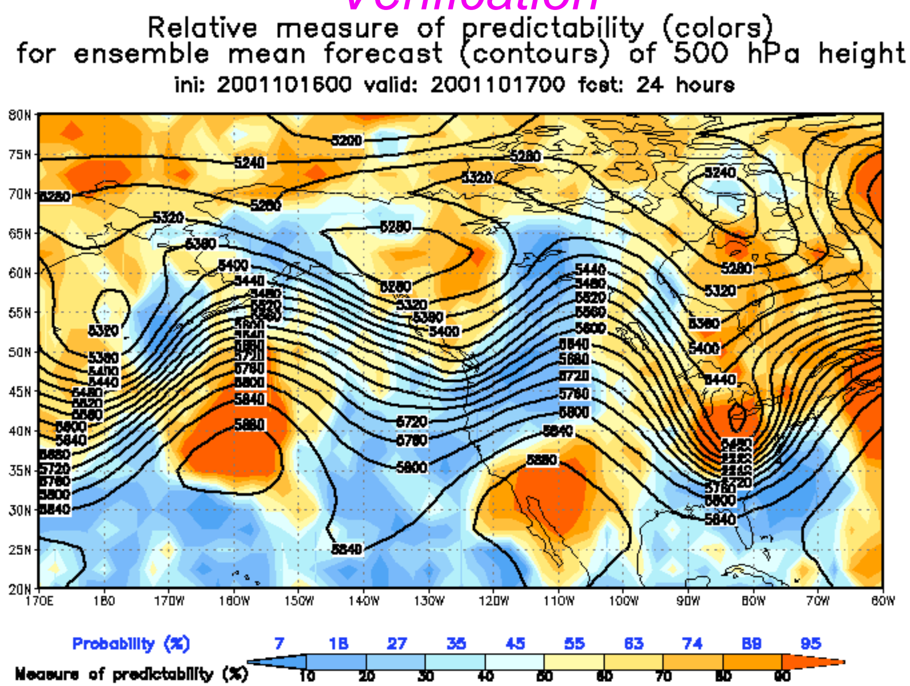


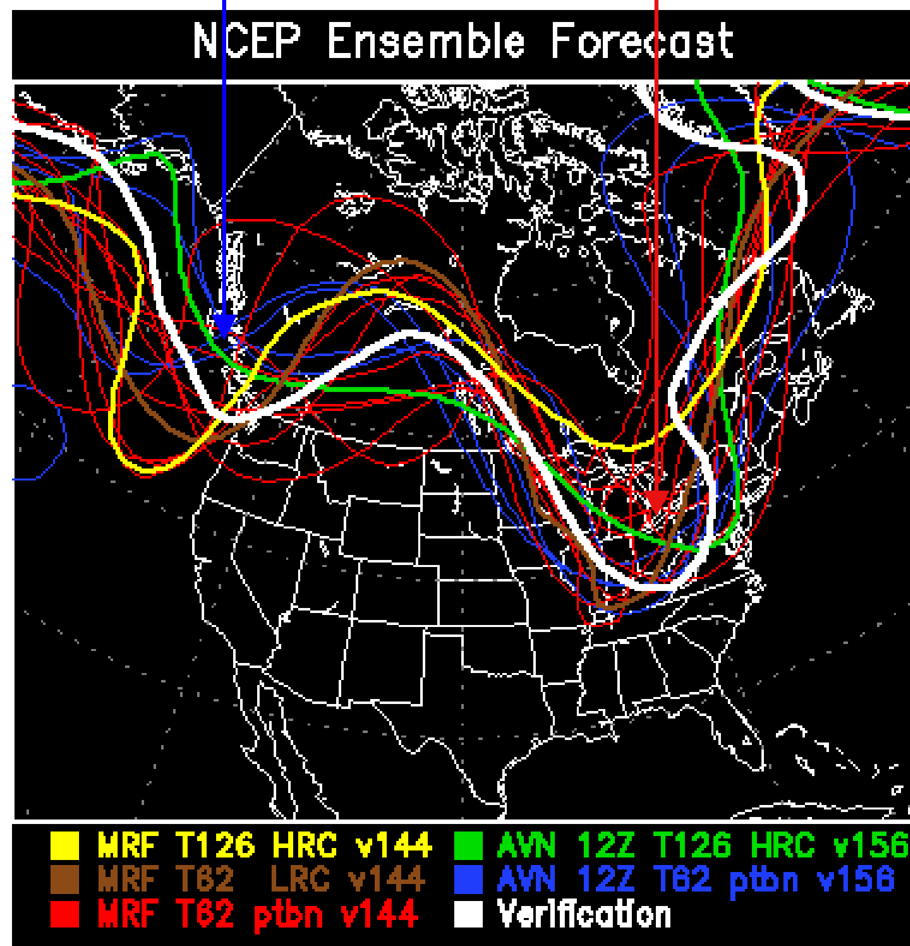
144 hr forecast

Poorly predictable large scale wave
Eastern Pacific – Western US

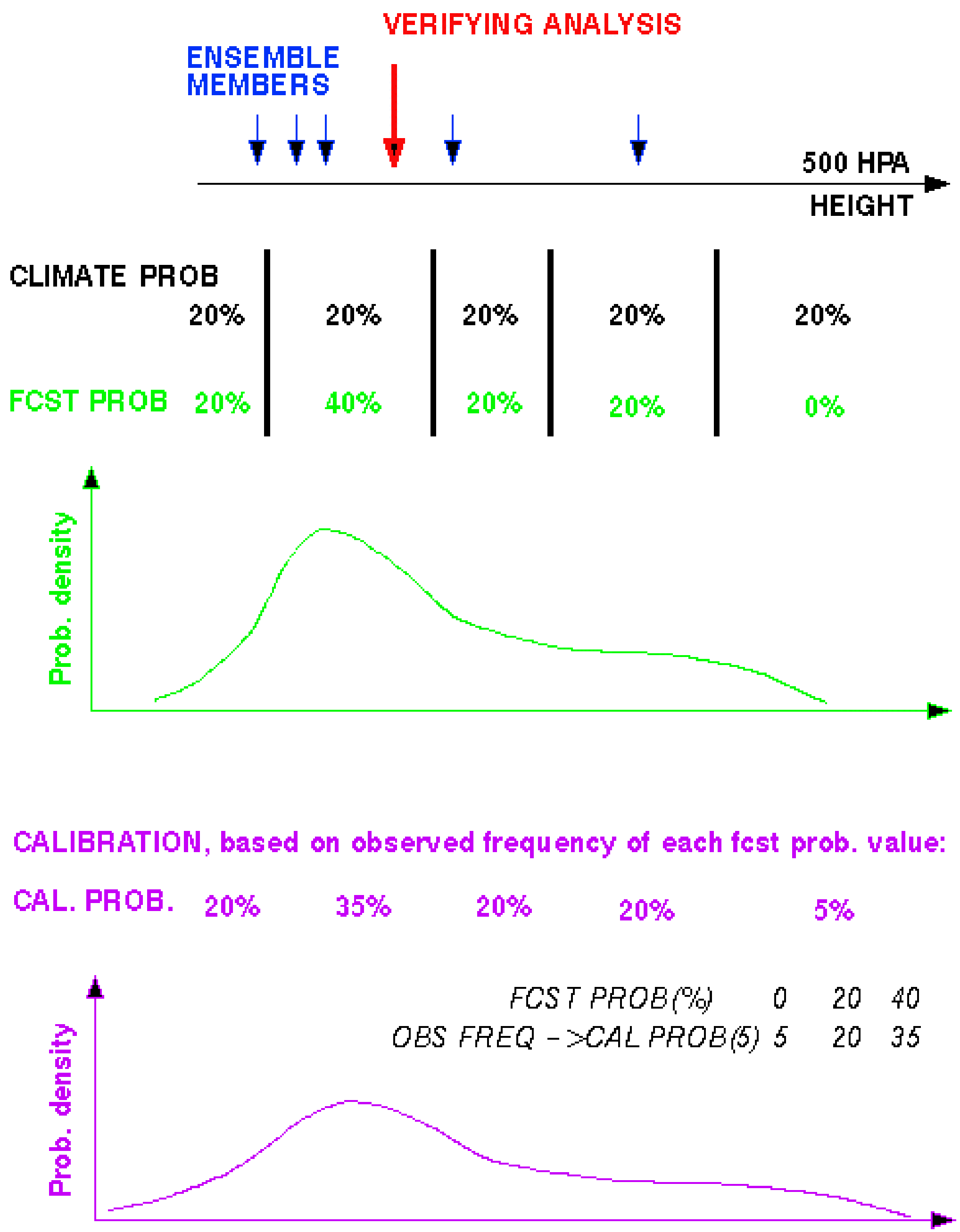
Highly predictable small scale wave
Eastern US

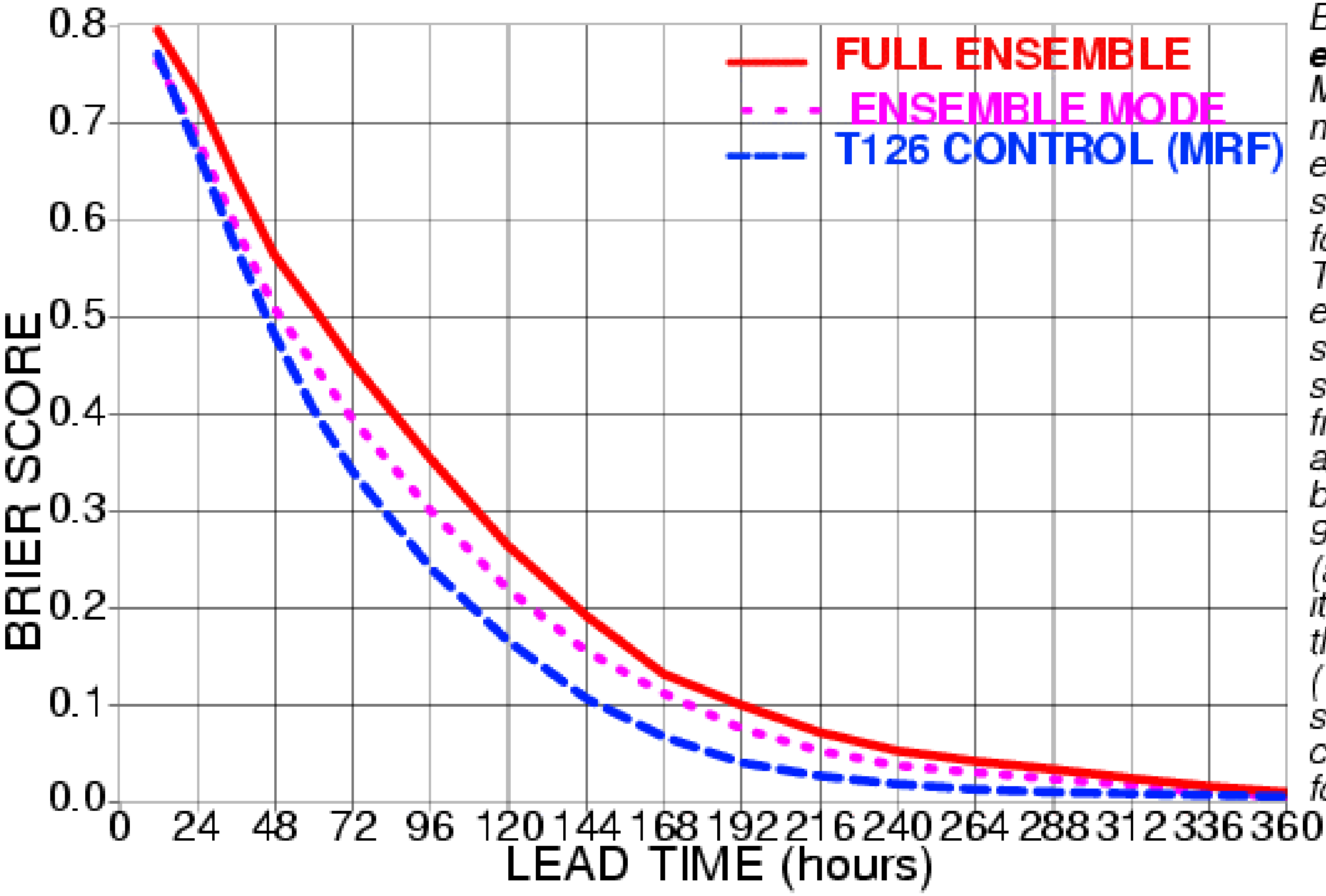
Verification





ENSEMBLE BASED PROBABILISTIC FORECASTS AND THEIR VERIFICATION





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